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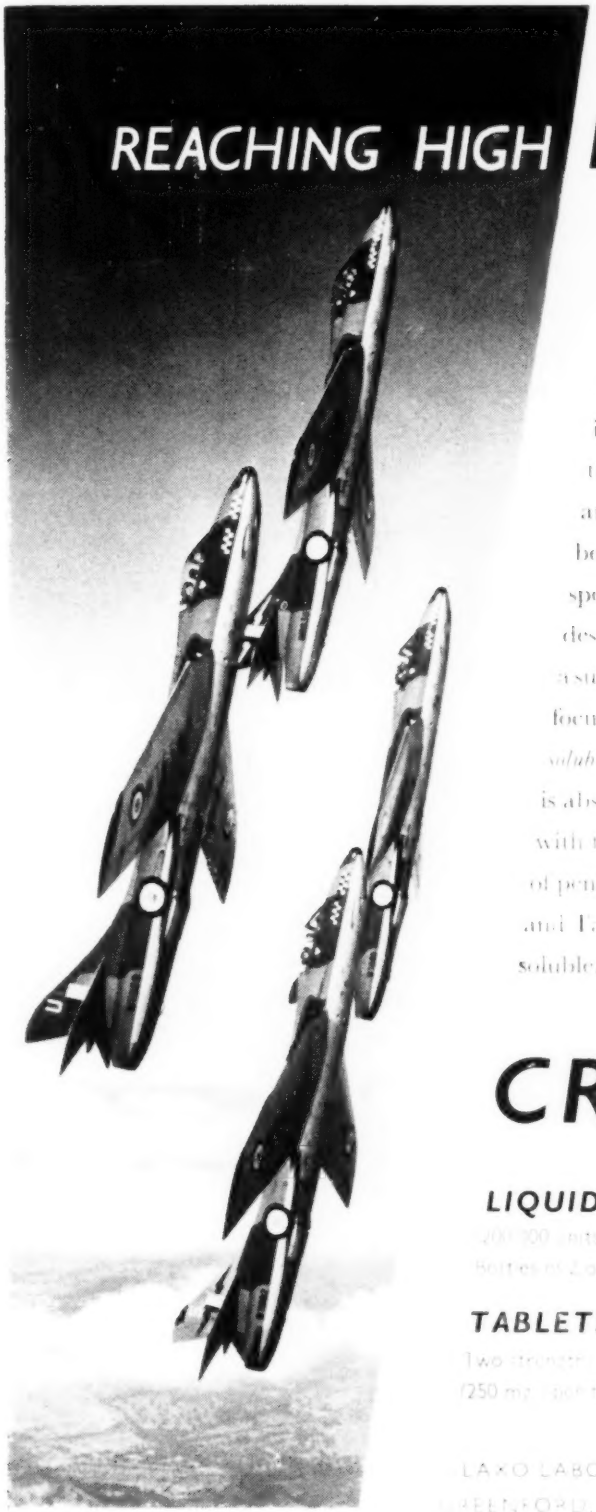

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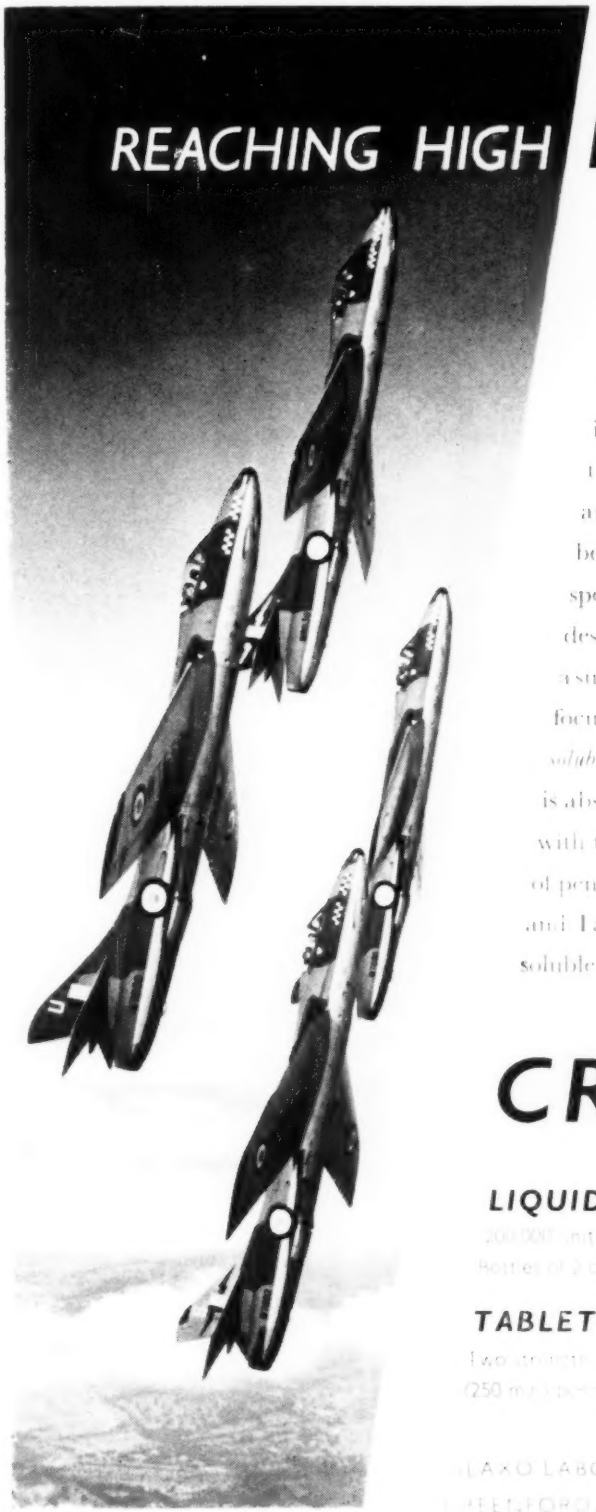

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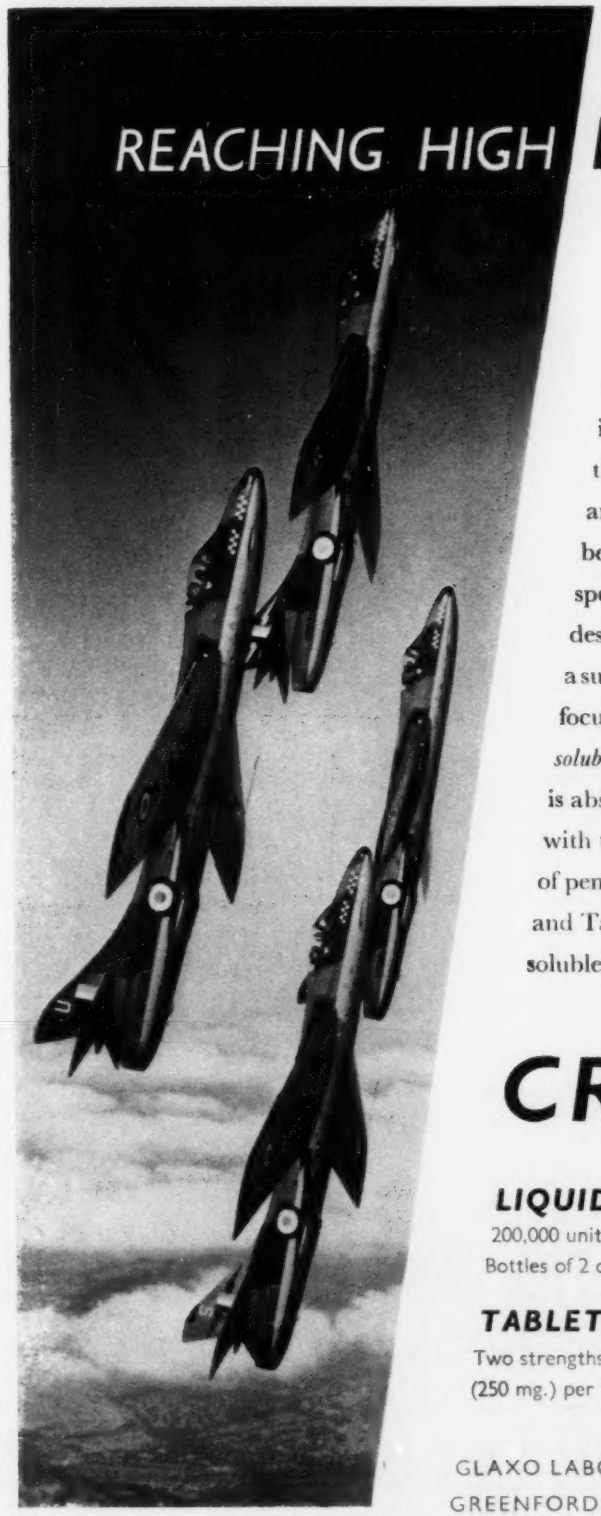

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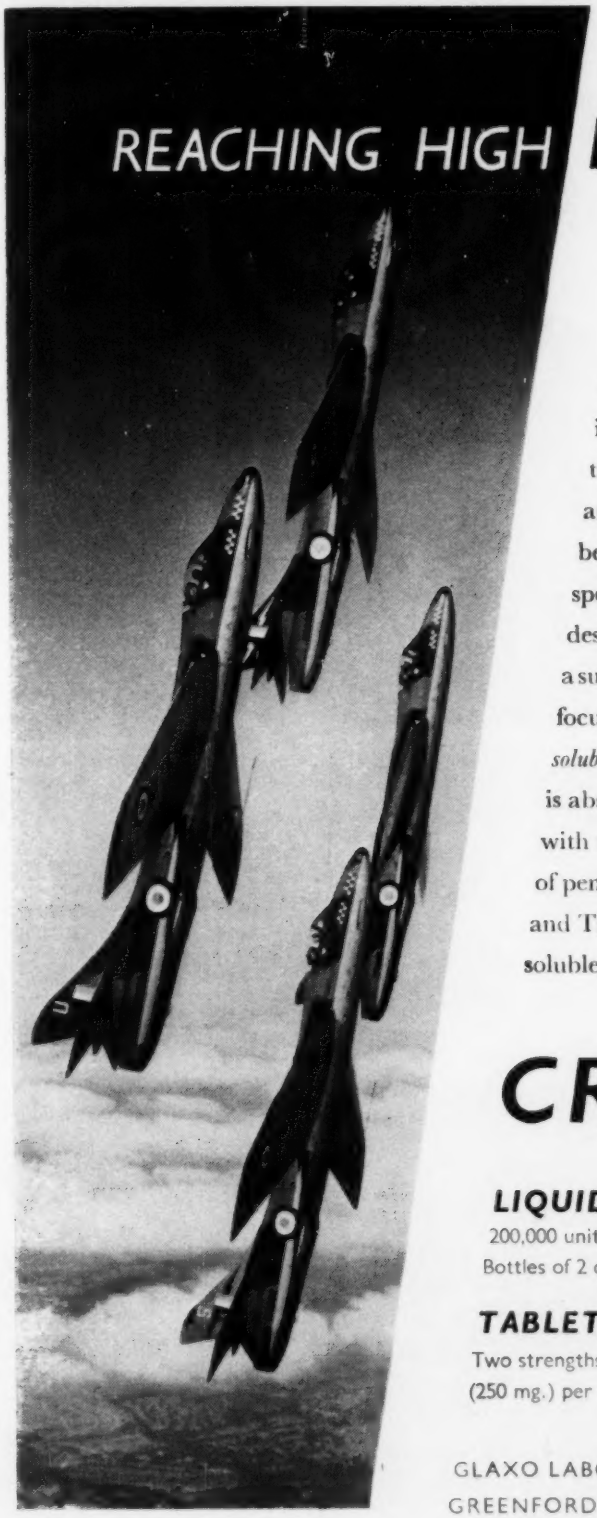

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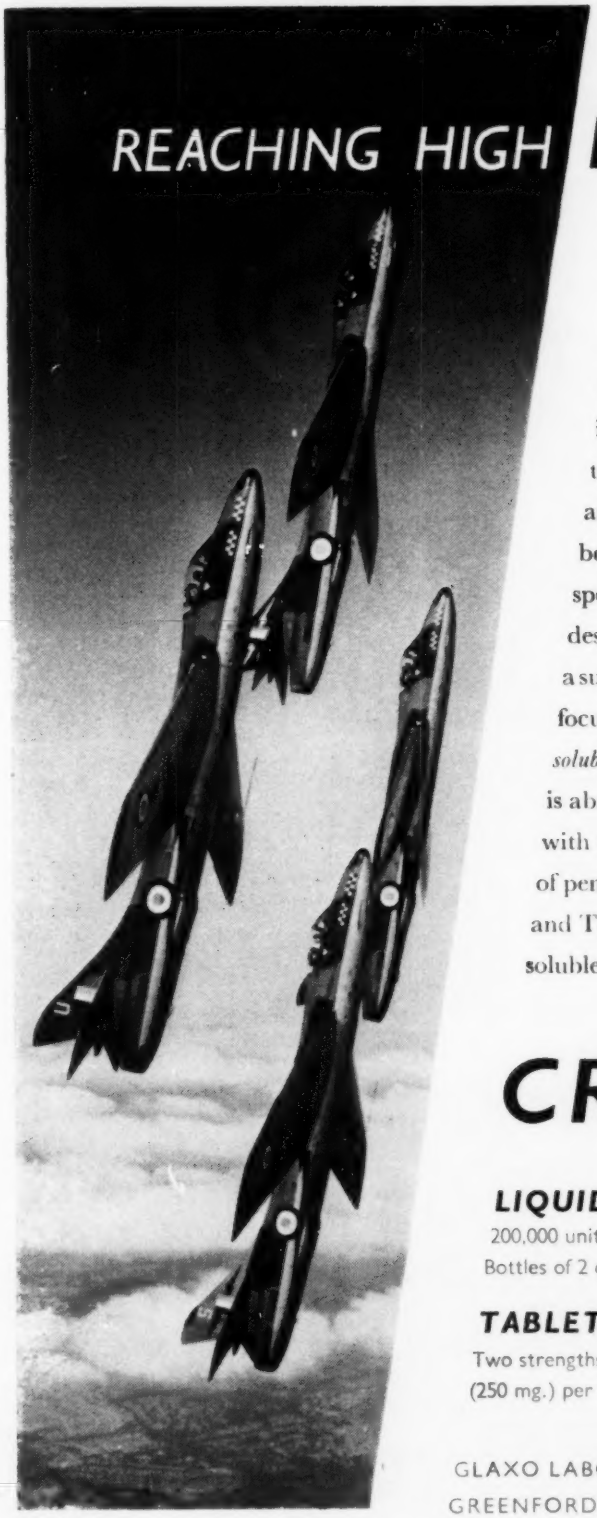

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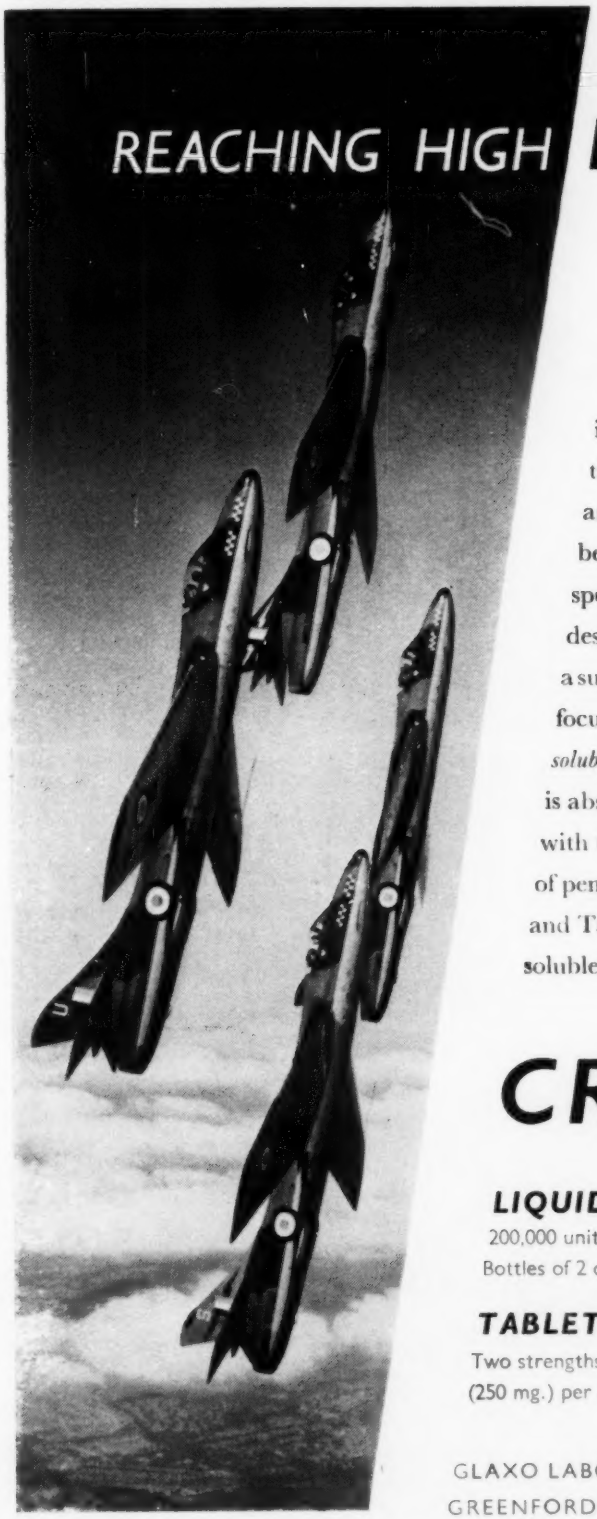

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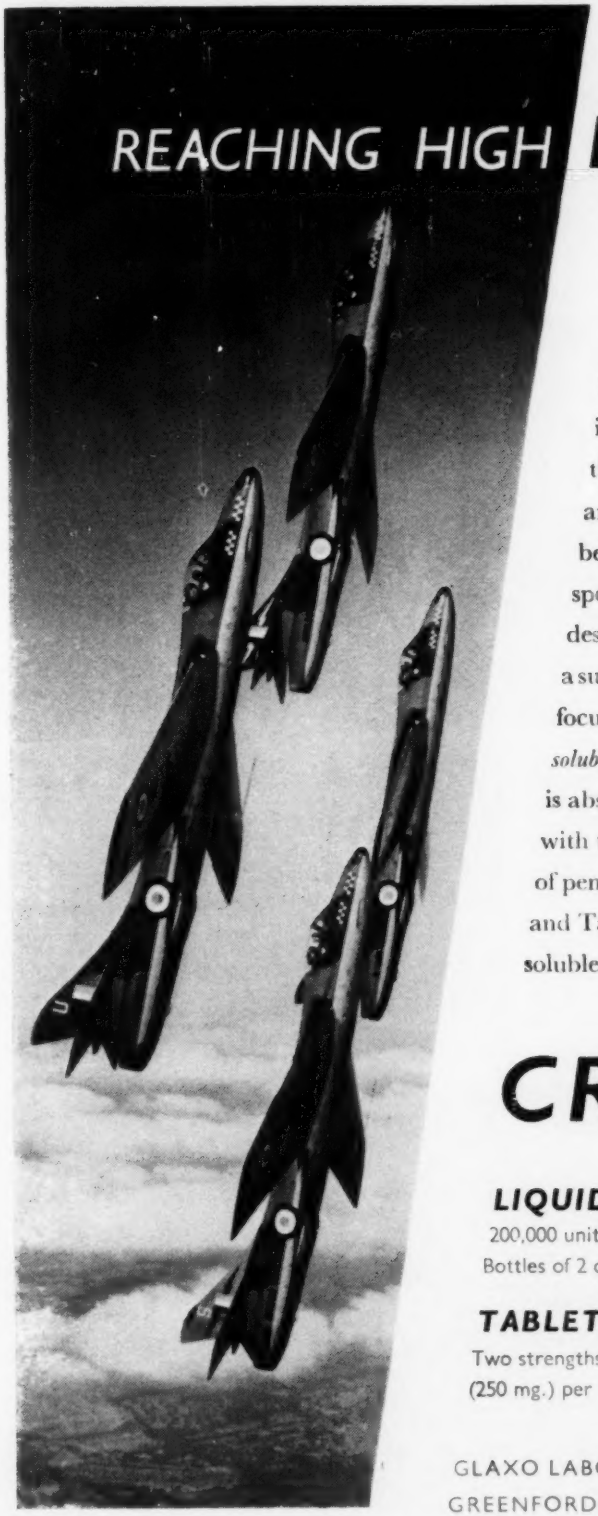

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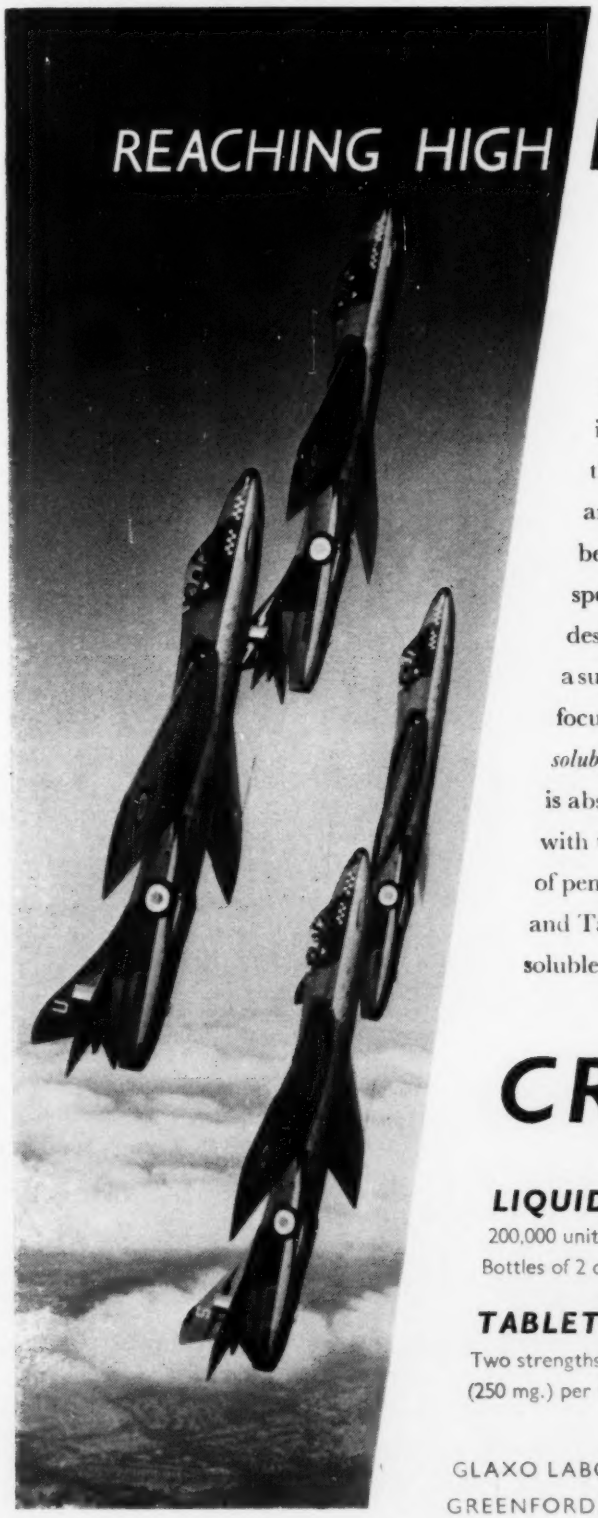

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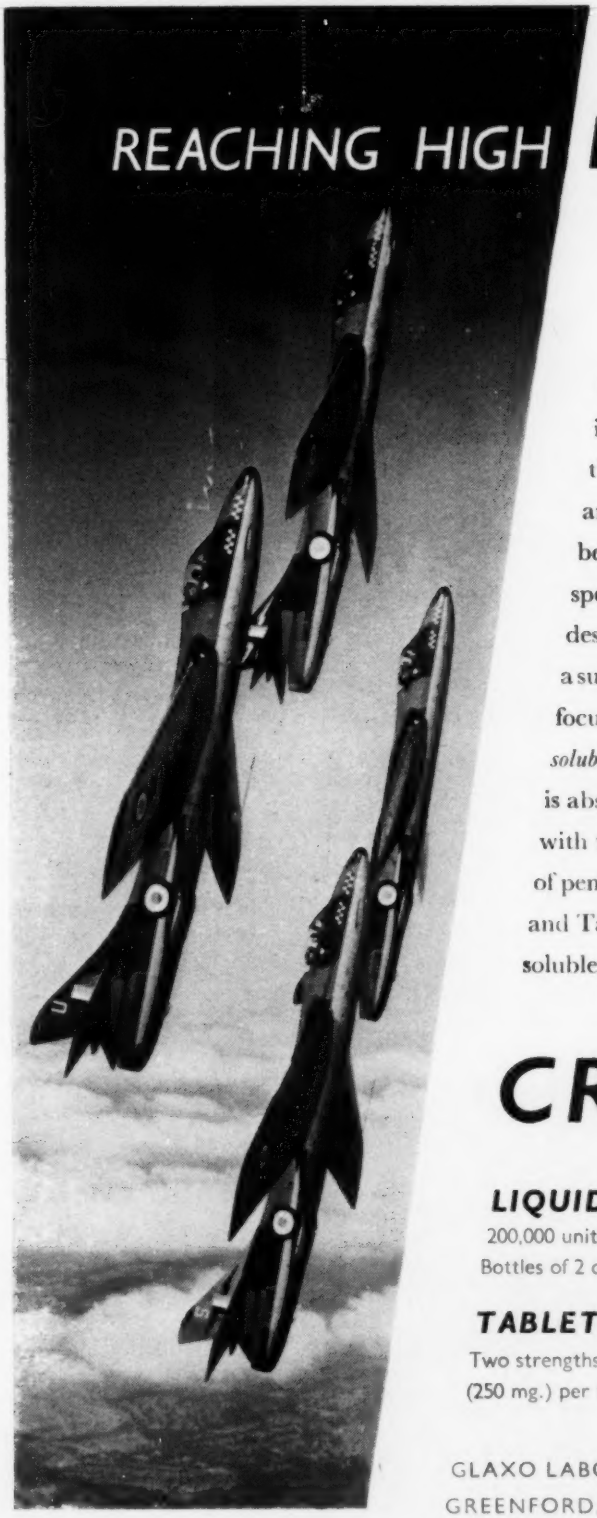

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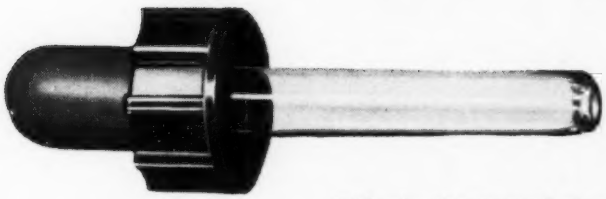

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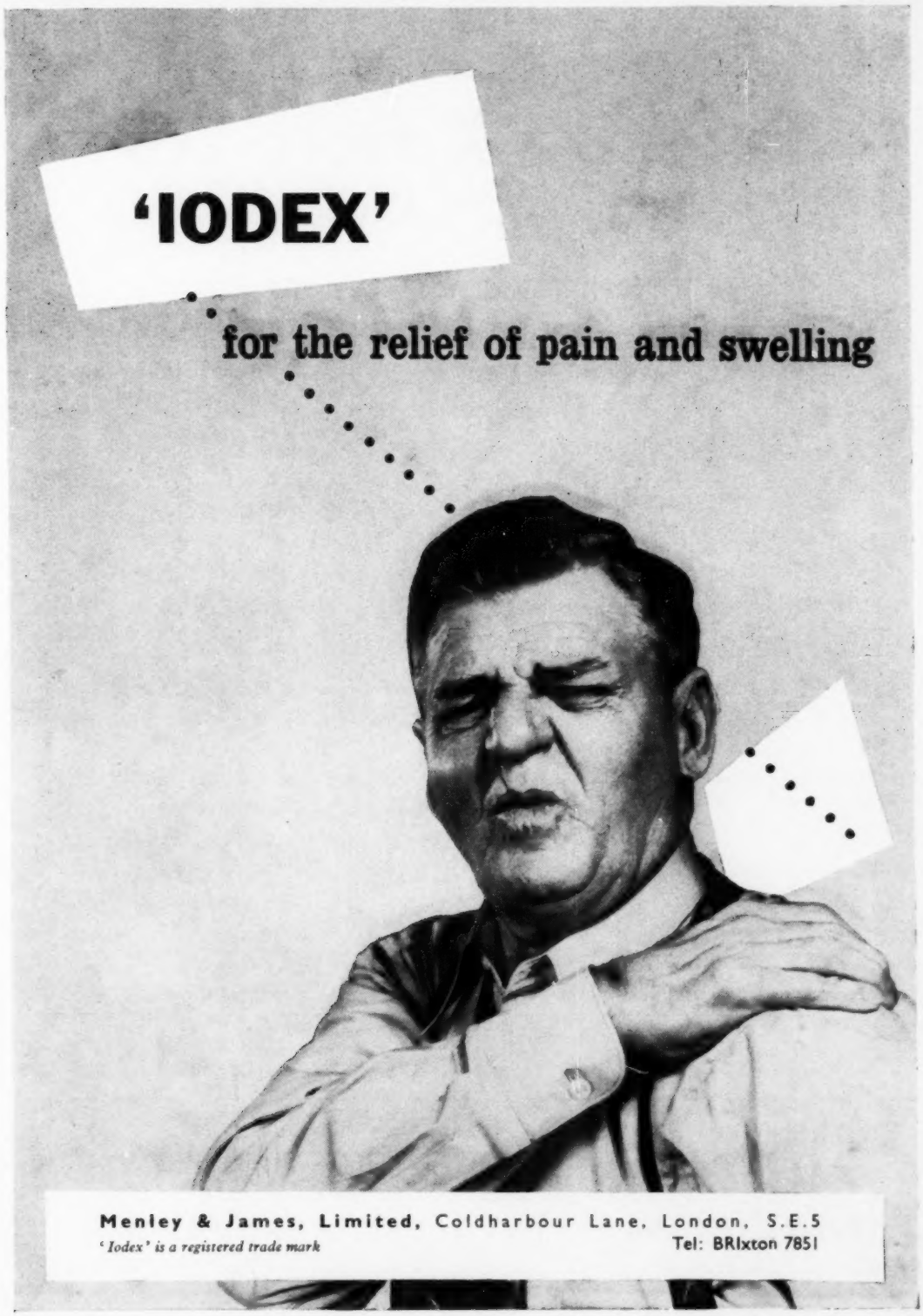
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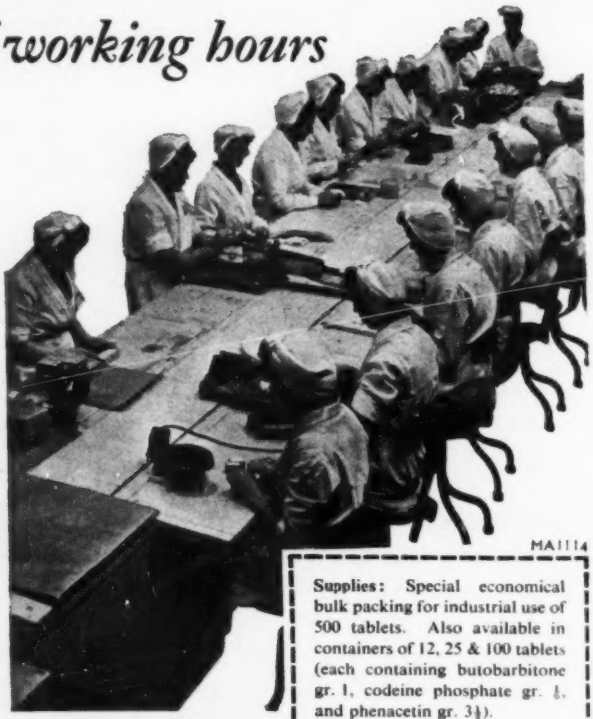

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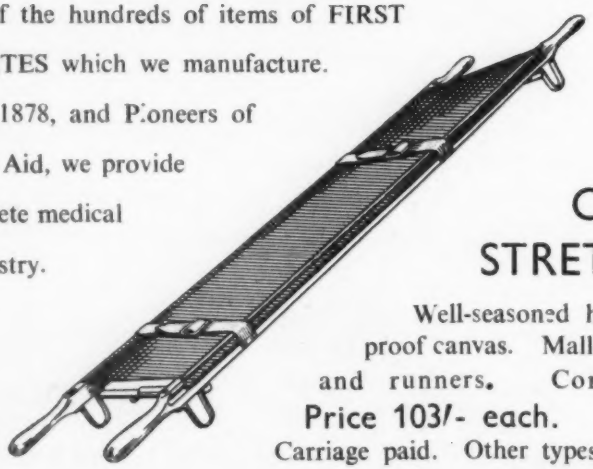

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A CLINICAL STUDY OF A GROUP OF ACCIDENT-PRONE WORKERS*

BY

JAMES A. SMILEY

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One of the many difficulties in the study of accident causation is to keep under detailed medical supervision a group of men exposed to constant risk who provide a sufficiently large number of apparently accident-prone individuals. At the end of 1944 the prospects of continued employment were good. In an area where there was little alternative employment available, 300 men, who in that year had sustained an undue number of accidents, were selected from a total population of 6,450 employed in an aircraft factory. It was felt, as accident proneness might not prove to be a stable quality, that as large a group as possible should be studied.

Eighty-seven men of this group of 300 proved to be prone to accidents during the year 1945. This paper is concerned with the observations made on them and on a random sample of 100 other men from the same factory.

Schilling (1954) in a brief review states :

> " From a number of investigations both Arbous and Kerrich (1951) and Ghiselli and Brown (1948) conclude that the low degree of consistency which exists between the accident rates of individual workmen for separate periods of time may be because the tendency to have accidents is an unstable trait. Much of the evidence of its stability is based on minor accident records. These may be unreliable indicators of accident proneness since some workers get almost every minor injury treated and others do not. Thus, *recorded minor* accidents may indicate a personal trait which is stable but not necessarily associated with accident proneness."

During the early years of the war in the aircraft factory where this work was done there had been serious labour trouble because of a condition which workers called " alclad poisoning". On investigation it proved to be a low-grade subacute infection of relatively minor (as well as major) cuts and abrasions. As the result of the panic and the measures taken by the medical and supervisory staff in the factory, it is reasonably certain that a high standard of reporting minor accidents was achieved. In 28 similar factories the average rate of accidents reported per man per year was 1·53 as compared with our rate of 2·1. In the year under review over our whole organization more than 48,000 accidents were recorded in our day-books. Of the cases recorded, 336 developed sepsis during treatment but only one of these men had failed to attend initially when his accident had occurred. It is therefore claimed that extremely few accidents were not recorded.

The accidents studied have been for the most part minor, such as cuts, abrasions, and bruises. The number of accidents which might be classified as serious, *e.g.*, those involving absence from work for two or more days, being just less than 1% of the total, was insufficient for statistical purposes. That this procedure is legitimate is sustained by the work of Farmer and Chambers (1929) and Greenwood and Woods (1919) who showed that those who had an undue number of minor accidents had also an undue number of major accidents. " This implies that those specially liable had more accidents, both minor and major, than others with a lower degree of liability." (Newbold, 1926). Further, the gravity of an accident is apparently fortuitous so that many peculiarities in the distribution of accidents in any large group of men is common to both major and minor accidents. " Accidents of this kind (trivial) are also important in another respect. Since the cause and effect of an accident are unrelated in magnitude, it is immaterial for the study of certain aspects of causation whether the result of the accident is serious or not, and hence data relating to trivial accidents can, with certain precautions, be used to draw conclusions applicable without modification to accidents generally." (Osborne, Vernon, and Muscio, 1922). These precautions have been taken.

It was considered desirable to estimate whether any particular group of workers was exposed to a greater risk than any other. To obtain a sufficiently large group of certain occupations, the accident

*The Milroy Lectures delivered before the Royal College of Physicians in London in February, 1955.

frequency rates per 100,000 man/hours worked over the whole organization were calculated and found to be approximately similar. No attempt has therefore been made to adjust our figures for infinitesimally small variations in the exposure to risk.

Identification of Accident-prone Group

Fourteen thousand four hundred and ninety-eight accidents were recorded in the day-books of the main factory. Nine hundred and fourteen accidents incurred by drivers of trucks and other vehicles in inter-factory transport together with a number sustained by employees of building contractors were eliminated because it was known that other accidents incurred by this group were being reported and treated at other centres. Therefore the total number of accidents studied was 13,584 and these were distributed over 6,450 workers.

In Table 1 is shown the observed distribution of accidents. On the assumption that accident causation may be a matter of chance only, the Poisson distribution was calculated. It obviously does not fit so that the chance explanation is unacceptable. It has been shown that the negative binomial distribution (first applied to accidents by Greenwood and Yule) can arise on either of the two hypotheses: (1) Fixed but unequal proneness to accidents of the exposed, and (2) the same initial probabilities for all the exposed but the probability of an accident being increased linearly with the number already sustained. The negative binomial was also calculated as in Table 1, and, although it is an improvement, it clearly does not fit.

Arbous and Kerrich (1951) have shown that to discriminate between these two hypotheses it is necessary to examine the bivariate distribution in two separate periods of exposure to risk. This has not been possible in the present investigation but the weight of all the evidence in this and other studies is in favour of the hypothesis that those exposed to risk have an unequal proneness to accidents.

It will be noticed from the Poisson distribution that no worker in the factory would have incurred 10 or more accidents if they had been distributed by chance only. As all those who had incurred 11 accidents or more had remained in our employment during the period under review, we chose their records for study. These 87 men were exposed under one roof to a risk similar to that of their workmates, and had accidents which we postulate cannot be explained under any hypothesis other than that they had and continued to have a liability to sustain accidents. For purposes of comparison a random sample of 100 men working in the same workshop

TABLE 1
OBSERVED AND EXPECTED DISTRIBUTIONS OF ACCIDENTS

Accidents	Observed	Poisson	Negative Binomial
0	1,520	785	1,775
1	1,522	1,653	1,503
2	1,483	1,741	1,086
3	773	1,222	739
4	483	644	488
5	203	271	316
6	170	95	202
7	82	29	128
8	71	8	81
9	32	2	50
10	24	—	31
11 and more	87	—	51
Total	6,450	6,450	6,450
11	25	—	19
12	24	—	12
13	9	—	7
14	12	—	5
15	5	—	3
16	6	—	2
17	2	—	1
18	0	—	1
19	0	—	
20	1	—	
21	1	—	1
22	1	—	
23	0	—	
24	1	—	
Total	87	—	51

(4 = Observed, 11–24; 1 = Negative Binomial, 19–24)

was taken by withdrawing their clock numbers from a rotating drum. As the identity of the 87 accident-prone men was not established until the end of the year and as we were observing 300 who from their previous record appeared to be potentially accident-prone, we had the opportunity of making observations on nearly 400 men.

Clinical Methods

The Sister in charge of the nursing staff had a list of these men, and during the year (according to the exigencies of the situation in the consulting room as well as in the factory) she daily presented one, two, or three for examination. Her method was usually to tell a man when he attended the surgery for any minor purpose, *e.g.*, the dressing of an abrasion, that the doctor wished to see him. Occasionally she summoned a man from his work bench. We deliberately kept each man waiting for some minutes without informing him of the purpose for which he was required and thus excited in those who were not quite indifferent, minor degrees of curiosity or apprehension—according to their temperament. It was thought that by subjecting the men to some degree of emotional stress a latent symptomatology might declare itself more clearly. I was not told to which group each man belonged but sometimes I recognized a man as belonging to the potentially accident-prone group. The correlation of statistical evidence with clinical findings has

always been difficult—not least with those intangible elements which comprise personality. After much consideration Culpin's classification as described in *The Nervous Temperament* (Culpin and Smith, 1930) was adopted (see footnote to Table 6). It seemed at the time to be the best for our purposes, for it lent itself to statistical methods of study. Where subjective criteria preponderate over objective, the interviewer has constantly to be on guard lest his standards vary. So the results of classification were repeatedly compared and regularly checked against each other.

Culpin's Grouping

It is necessary to record briefly how the nervous grouping of each individual was assessed, First of all the general appearance of the man was noted—the presence or absence of furrowed forehead and wide palpebral fissures, the stability or otherwise of the pulse rate and the presence or absence of blushing, together with the demeanour, whether aggressive or unobtrusive. Questions were asked about the man's job, his hobbies, and his general mode of life, and an effort was made to discover whether he was in any degree frustrated by any unreasonable fears or anxieties. For example, one man had been a charge-hand but had requested to be returned to the bench because he did not feel " up to it". He blushed violently when the subject of his request was discussed with him. He stammered slightly. As a fitter he was amongst the best in the factory. He exhibited other symptoms ; *e.g.*, when asked what his reaction would be if summoned by the Personnel Manager, he said that he knew " it would be to get my cards", meaning that he was to be dismissed (classified Group 4). Having enquired into the presence, or absence, of what appeared to be unreasonable fears, I next turned to the field of needless activities—the inability to relax or rest ; and also to learn the reaction to any disturbance of abnormally fixed habits of life. Then, if it had not already come out in conversation, enquiry was made into the question of mood ; whether, for example, the workman had alternately depression and normality, the frequency of the alternation and, if possible, the intensity. The attitude of the individual, not only to those in authority, to his equals and his subordinates, but to himself, *e.g.*, whether or not he was well adjusted and had insight, was also taken into account. During the interview, too, his attitude to work and working conditions became manifest, *e.g.*, whether work was satisfying, whether noise, cold, and environmental conditions assumed disproportionate significance. If it had not already emerged in conversation, enquiry was made of the reaction in more general situations, *e.g.*, fear of the dark, of heights, indecision in traffic, and so on.

Sometimes this system was not followed because, when the conversation was initiated, all the information needed for classification came spontaneously from the patient.

The fact that scoring in my control group is not markedly at variance with Culpin's own experience of rather different types, and corresponds very closely to that obtained by Davies and Wilson (1937) in their sample of herniated hospital patients, justifies me in the belief that our standards, subjective as well as objective, were similar and strictly comparable, or that we were all subject to the same errors. It tends to confirm, too, that a fairly uniform set of standards was maintained throughout the investigation.

Culpin's classification has the advantage of allowing us to classify men whose condition could not be considered either grossly abnormal or permanent. Many men would not exhibit symptoms of the anxiety state if the stimulus of anxiety was not great. Their reactions may be almost normal although symptoms are present, because circumstances over which they have little or no control bear heavily on them. The group to which each man was allocated was the one found at the interview during the period when he appeared to the Sister-in-Charge to be accident-prone and was sent to me. On a number of occasions individuals who had been rated as in classification 3, 4, or 5 when seen subsequently, after their particular anxieties had been resolved, would have been down graded by two grades. As an example the case history of a fitter aged 29 is typical. Five years previously his fiancée died. His father, mother, one sister, and two brothers were killed in an air raid on Belfast in 1941. He went to live elsewhere and became engaged to the daughter of his host. His second fiancée died suddenly on March 16, 1944, and at first inexplicably. The inquest was adjourned and police enquiries followed. He had six accidents in the first week after this catastrophe. On interview he was restless, agitated, showed marked tremor and stammer. He had some agoraphobia, headache, and slept little. He was disturbed by dreams, the most frequently recurring being that he was sitting near the centre of a huge revolving gramophone disc, the centrifugal force of which was driving him nearer and nearer the circumference until, eventually, when he was flung into space, he awakened trembling, bathed in perspiration. The following week he had five more accidents in three days immediately before the adjourned inquest.

He was classified in Group 4. He took 10 days' holiday and during the remainder of the year had no more accidents. Later he was classified in Group 2.

There was only one clearly psychotic workman. He had definite persecutory delusions and had obtained numerous transfers from one department to another—perhaps not without reason, for his name was Hess. He had, however, hallucinations and brought me to a gun turret to see his non-existent tormentors. He was classified Group 5.

Distance from Work

The factor of fatigue is considered by some to be important in accident causation. The amount of time required to travel to work was chosen as probably more important than the distance from work. No significant difference between control and accident-prone groups, so far as long journeys are concerned, was noted.

The average time spent in travelling, surprisingly, was found to be five minutes less for the accident-prone group than that for the controls (31·2 minutes as compared with 36·1). A possible explanation for the difference was that among those living within the city boundary there was a greater tendency amongst the accident-prone group to cycle to work.

Lost Time

When considering the number of days lost each year and noting the large amount of lost time, it should be remembered that in this year there were 350 working days. The average amount of lost time for all causes in the accident-prone group was 75·2 days and in the control group 29·9 days. This corresponds with the experience of Newbold (1926). The great discrepancy here is not fully explained by the time lost as the result of accidents, nor, if the medical certificates issued to account for the absence from work of these accident-prone individuals is scrutinized, is it accounted for by any easily definable clinical entities.

Chronic Organic Lesions

Chronic organic lesions were revealed during the examinations. Some of these were detected clinically, but some, *e.g.*, peptic ulcers, were suggested only by the history. In no case is peptic ulcer recorded where the diagnosis was not confirmed by test meal and radiograph during the year under review, or by the perforation of an ulcer.

Many of these workpeople, especially in the accident-prone group, complained of " rheumatic pains " but when there was no objective evidence of any lesion, no record was made of them. The erythrocyte sedimentation rate of all those who so complained was estimated and only in one case was it found to be above normal limits. As will later be seen, many of the accident-prone group were working under emotional tension and unfortunately association between this and the complaint of " rheumatism ", " fibrositis ", and the like was not detected sufficiently early in the investigation for its significance to be determined. Flind and Barber (1945) have described the close association between the neuroses and the incidence of " rheumatic pains". In those cases classified by me as " rheumatism " there was a demonstrable lesion. Migraine and petit mal (one case each) are included under the heading " chronic lesions ". This has been done to avoid still further sub-classification although no demonstrable organic lesion existed in either case. Another case was that of an ambitious young fitter who spent all his leisure hours " taking classes at the Tech.". He was tall, thin, active, and blond. He disliked being alone in the dark and on being pressed for a reason said vehemently, " I hate cats ". He would think that he would be " on the mat " if sent for by his foreman (a most reasonable man). The difficulty uppermost in his mind, however, was a tension which resulted from an unreasoning desire to be the last to leave his department at the end of the day and at the same time an equally powerful urge to catch the first bus leaving the works so that he would be in time for his evening classes. The conflict was never finally resolved and had to be fought each day. His foreman gave us the information that after locking his box of tools the lad would walk backwards still eyeing it until he was out of the department and would then hurry away, but that frequently he would return once, or more than once, to examine his lock or look at the bench to see if he had packed all his tools—*sentiment d'incompletude*. This man was classified as an obsessional in Culpin's Group 4. At intervals of about 10 to 12 days he was incapacitated by attacks of migraine which lasted two days, and for that reason his absences are classified under the heading of " chronic ".

Another man (known to all but his friends as " Dopey ") suffered more from bromide and barbiturate intoxication than petit mal. His nervous group is queried because although he had definite symptoms his intelligence was of a low order and his mental reactions were slow. It was therefore difficult to interview him, but he was classified in Culpin's Group 2.

Acute Organic Lesions

It was difficult to define what lesions to include in the term " acute ". Not all acute lesions are

completely incapacitating and yet some men will stay away from work for a cause which could be justified, while others, with more acute lesions, will remain at their benches. On the other hand liability to accidents may be affected by such a complaint as a common cold. However, as common colds are not compulsorily reportable and some men stay away while afflicted and others do not, it was thought advisable to record only the more severe acute illnesses, *i.e.*, those necessitating an absence from work of more than seven days and therefore supported by a medical certificate. The most common entries are " boils " and " gastro-enteritis ". In those cases where boils are recorded the infection was severe—either a crop of small boils or one very large one—but always sufficient to incapacitate completely for at least seven days. It usually happened that those men were at work while the infection was developing and returned before it had subsided. The cases of gastro-enteritis were not examined bacteriologically, and it might be argued that the diarrhoea was symptomatic of their emotional stresses. Against that is the fact that gastro-enteritis was epidemic in the factory some months before this study was started. Further, none of those affected showed evidence of undue emotional strain in any other way. Our experience was that the victims remained at work until their symptoms drove them home.

All vague diagnoses were excluded from this group, *e.g.*, " fatigue ", " nerves ", and " gastritis ", usually after communication with the patient's own doctor.

One man was recorded as having an acute organic lesion because he returned to work ten days after an operation for acute appendicitis. No lesion was found. Immediately on his return he had a series of accidents. He might be classified as post-operative debility.

Two cases of defective vision are included in the acute lesions because of their extreme degree, amounting almost to blindness in the absence of correcting lenses. At the time both these men were having their spate of accidents their spectacles had been broken ; owing to immediate post-war difficulties, one had to wait seven weeks and the other nine weeks for repairs. The association between their visual defects and their accidents was too obvious to be ignored.

Sweating and Albuminuria

It has been noted in the routine examinations of accident-prone men that traces of albumin were frequently found in the urine, and that an unusually large number of them showed beads of sweat trickling down the thoracic wall from the axillae. Examinations also showed that their hands were moist with sweat, and their feet were almost invariably cold and clammy. It was decided, therefore, to make special enquiry into these points for the purpose of this investigation. Four cases in which albuminuria was found are not considered in this group because an organic cause was demonstrable, *e.g.*, hypertension or chronic nephritis.

Results

Table 2 shows that an almost identical percentage of each trade is represented in the accident-prone and control groups. This is evidence that in our particular assembly factory no worker is rendered more liable to accidents than another by reason of the nature of his occupation. It does not mean, of course, that there are no jobs involving a higher degree of risk than others. There are, but they are so relatively few and of such short duration that they are unimportant.

TABLE 2
ALLOCATION OF ACCIDENT-PRONE INTO TRADE GROUP

Trade	No. in Accident-prone Group	% in Accident-prone Group	% in Control Group
Fitter	47	53	52
Riveter	16	19	20
S.M.W.	10	12	13
Labourer	9	10	9
Electrician ..	5	6	6

Table 3 shows that almost twice as many of the 26–35 age group are found amongst the accident-prone as amongst the controls. In view of the very small numbers, this may not be significant of itself but is suggestive.

TABLE 3
INCIDENCE OF ACCIDENT-PRONE IN DIFFERENT AGE GROUPS

Age Group	No. in Accident-prone Group	% in Accident-prone Group	% in Control Group
15–25	39	45	43
26–35	26	31	17
36–45	14	16	23
46–55	6	7	11
56 and upwards	2	2	6

Attendance at Medical Department.—The number of times each individual came to the Medical Department for reasons other than accidents was recorded. The average number of times in a year that a worker in the accident-prone group reported was 31. The control average was 13. From these figures and clinical experience it is deduced that the accident-prone do not have such a tendency to be sick as to feel sick or to report sickness

—probably both. It was found, however, that the accident-prone individuals not only report sickness more often but actually have peptic ulcers and other organic illnesses more frequently than the controls.

It seems clear, therefore, that there are amongst the accident-prone group a considerable number with peptic ulceration, and a smaller (by comparison with the controls) number with other chronic and acute conditions.

If, however, all these are excluded from the calculations, the average number of attendances at the Medical Department is almost twice as high in the accident-prone group as in the control group, and that the same ratio holds true for " lost time ". It would appear, therefore, that there is a residuum in the accident-prone group which tends to lose time and report illness without obvious organic cause. In the control group approximately 30 days (29·96) were lost on the average from all causes in the year, and in the accident-prone 75 days (75·2). If from each group the amount of time lost by accidents incurred at the factory is excluded, 26 days are lost on the average by men in the control group from sickness, while each of the accident-prone lost 55 days.

Organic Illness.—As summarized in Table 4, we find that (1) peptic ulcer occurs seven times more frequently amongst the accident-prone than in the controls, (2) chronic disabilities four times more often, and (3) acute lesions three and a half times more often. If, however, we now deduct the amount of time lost as the result of these conditions there is a residuum of 22·2 days in the accident-prone and 6·1 in the controls either not covered by medical certificate or attributed to a vague symptomatology of short duration. These data are not tabulated because they are not purely objective, and are open to criticism. Further, they may include some malingering.

TABLE 4

INCIDENCE OF ILLNESS IN ACCIDENT-PRONE AND CONTROLS

Subjects	% with Peptic Ulcer	% with Other Chronic Conditions	% with Acute Ailments (more than 1 week)
Accident-prone ..	15·6	20·4	21·6
Controls	2	5	6

It would appear, therefore, that not only peptic ulcers, chronic organic disease, and acute illness are associated with high accident rates, but also a group of other disorders concealed under various ill-defined diagnoses.

Functional Disorders.—As those classified in Groups 0, 1, and 2 merely exhibit what might be regarded as personality traits, but those in the higher groups require some assistance towards mental and emotional adjustment, it will simplify comparison if these groups are aggregated as in Table 5.

TABLE 5

AGGREGATED ANALYSIS OF ACCIDENT-PRONE AND CONTROLS ACCORDING TO CULPIN'S GROUPING

Subjects	0	1	2	3	4	5
Accident-prone ..		27·6%			72·4%	
Controls		92%			8%	

From this Table and Table 6 it will be seen that nine times as many of the accident-prone are emotionally unstable as the controls, and herein may be found the explanation of the group with the indefinite diagnoses offered in good faith to explain absence from work. These diagnoses vary from " rheumatism " to explain vague non-articular pains to " dyspepsia " for which investigation had found no cause, from " chronic inertia " from one unsympathetic doctor to explain a disinclination to face a temporarily difficult situation in the workshop, to " debility (pseudo) " to account for absence from work which in reality was precipitated by an acute domestic crisis in which the workman was involved but over which he had little control.

TABLE 6 *

DISTRIBUTION OF MEN IN ACCIDENT-PRONE AND CONTROL GROUPS ACCORDING TO CULPIN'S GROUPING

Group	0	1	2	3	4	5
Actual number in accident-prone group	0	5	19	32	30	1
Percentages in accident-prone group.. ..	0	5·8	21·8	36·8	34·4	1·2
Actual number in control group	8	38	46	5	3	0

* Culpin's groupings are briefly as follows :

0 = no particular symptoms
1 = one or more slight symptoms
2, 3, 4 = several symptoms, graded according to severity
5 = symptoms sufficiently severe to require treatment

It may be deduced that difficulty in emotional maladjustment is an associated and potent factor in accident proneness.

If we now examine the " nervous grouping " of all the men with peptic ulcer examined in the course of the investigation we find that without exception all 14 are classified in either Group 3 or 4—an interesting finding not without relevance to the subject of this study. These results seem to indicate that peptic ulceration is a complication occurring

in a type constituted with a certain kind of personality—the unduly anxious or emotionally unstable.

The two men in the control group who had peptic ulcers not only scored high in Culpin's classification but they also incurred more than twice as many accidents as the average of their group, which is 2·6. They, too, may be accident-prone although chosen at random as controls, and for statistical reasons excluded from the grossly accident-prone group.

One of the most positive findings in the whole investigation will, however, be seen when those who exhibited albuminuria (without obvious renal damage) and sweating are scrutinized. In the control group seven men at the time of the examination had traces, or more, of albumin in the urine, whereas in the accident-prone group 45 men, or 52%, exhibited this sign without obvious organic cause. If we compare those of the accident-prone group in whose urine albumin was inexplicably found with their nervous groupings, as in Table 7, it will be seen that 91% fell into the higher groups and 9% into the lower.

TABLE 7

PATIENTS WITH ALBUMINURIA RELATED TO CULPIN'S GROUPING

Culpin's group.. ..	0	1	2	3	4	5
No. with albuminuria in accident-prone group	—	—	4	17	24	—
	9%			91%		

Even if we add the albuminurias found amongst the controls only 15% fell in the lower group and 85% in the higher. A glance at Table 7 will establish the importance of this finding, and the conclusion that there is a high degree of correlation between transient albuminuria and emotional instability can scarcely be resisted.

Among the accident-prone an initial desire to pass urine or a difficulty in voiding urine was observed much more frequently than in the controls. Detailed records of this observation were not kept for statistical analysis.

During the examination of the accident-prone in the period of time in which they were having their accidents it was noted that many of them were perspiring freely. Frequently large beads of perspiration could be seen coursing down the thoracic wall from the axillae, and almost invariably that their hands and feet were either quite moist or wet with sweat. The complete absence of sweat on other parts of the body was noteworthy. It was accordingly decided when doing the " set " examinations to record the presence or absence of this phenomenon.

In the control group 11 cases of hyperidrosis were observed, but in the accident-prone group 55 cases were seen, *i.e.*, 11% of the controls and 63% of the accident-prone exhibited sweating at the outset of the interview.

If we now compare the men encountered having this sign with their nervous groupings, we get the results shown in Table 8. Thus there is a clear association between this type of sweating and high scoring in Culpin's groups.

TABLE 8

ASSOCIATION BETWEEN SWEATING AND CULPIN'S GROUPING

Culpin's group.. ..	0	1	2	3	4	5
No. with sweating ..	—	13	—	—	53	—
	19·5%				80·5%	

Summary of Findings

The grossly accident-prone men on the average lost three times as much time from all causes as the controls. After deducting time lost as the result of accidents, the accident-prone men still lost twice as much time as the controls. The accident-prone men lost more time as the result of both acute and chronic illness. They tended to have peptic ulceration more frequently. Excluding organic illness, both acute and chronic, on the average the accident-prone still lost 22 days as compared with the controls who lost six days as the result of conditions either not covered by medical certificates or diagnosed in vague terms like " fatigue ", " neurasthenia ", " gastritis ", suggesting the absence of organic disease. The accident-prone attended the Medical Department three times more frequently than the controls for causes other than accidents. The travelling time to work of the accident-prone was five minutes less than that of the controls. (This was probably due to a greater tendency amongst the accident-prone living within the city boundary to travel by cycle.)

Seventy-two per cent. of the accident-prone when classified according to Culpin were in the higher group as compared with 8% of the controls, 63% of the accident-prone as compared with 11% of the controls exhibited palmar and plantar sweating, 52% of the accident-prone and 7% of the controls exhibited transient albuminuria. Also a temporary deviation from normal function of the bladder (either as frequency or inability to micturate) was observed very much more often in the accident-prone than in the controls. It is shown that amongst the subjects of this survey there is a close association between palmar and plantar sweating and emotional

instability and between emotional instability and albuminuria.

These results were obtained from a study of a group of men who were grossly accident-prone. It is unlikely that they would be found in such a degree of severity if all degrees of accident-prone individuals had been studied. Further, these results were obtained in men who, if they were not permanently accident-prone, were so constituted that they tended to have recurring bouts of accident proneness. Each one of those individuals who proved to be accident-prone during the year under review had been included in the survey because in the previous year he had had a bad accident record.

Discussion

Not much reliance can be placed on the statistics relating to acute illnesses. For several reasons they are incomplete or unreliable. The medical certificates issued to account for absence from work were frequently found to be unreliable. All vague diagnoses such as " debility ", " nerves ", and the like were excluded, and only absences for a period of at least seven days were included. There does not yet appear in the literature any satisfactory way of accurately assessing the importance of acute illness as a factor, if any, in accident proneness. It may be that after a prolonged absence by reason of a serious illness the element of " inexperience " re-enters as a factor even in the case of an experienced tradesman.

Age and Inexperience as Factors.—A consideration of Table 3 does not indicate that youth itself is a factor in accident proneness. Forty-five per cent. in the accident-prone group, as compared with 43% in the control group, fell into the lowest age group, 15–25. The element of inexperience is eliminated in this survey because recruitment of labour for this factory ceased some months before the investigation was begun. It may be, of course, that within the group itself changes in liability take place, *e.g.*, the boys of 15 years may have a high accident rate, and the young men of 25 years a low rate. Not a sufficiently large number of these ages occurred amongst the accident-prone to justify us in making a comparison from which to draw such a conclusion, but it does seem that inexperience, rather than youth, is the factor, because when inexperience is eliminated, as in this case, we have the same percentage of 15–25s in the accident-prone group as in the control. The investigation even of " inexperience " as a factor in accident proneness is difficult because, when large numbers of inexperienced workers, sufficient for study, are being employed, there is usually also a speeding up of production. It is common ground now, that accidents due to inexperience mainly occur during the first few weeks of employment, and rapidly decline thereafter. Farmer (1932) quotes Chaney and Hanna to the effect that accidents are five times more numerous during the first day's work than during the next five, so that during the last six months of the year they were 255 times less frequent than on the first day of the year. It cannot be deduced from Table 3 that because only 2% over 56 appear in the accident-prone group as compared with 6% in the control group that the middle-aged and older are less prone. The data are insufficient. Vernon and Bedford (1928) have found that accidents are less frequent, but more severe when they do occur, among the old. What does appear significant, however, is that 31% of the accident-prone, as compared with 17% in the controls, occur in the 26–35 age group, and that, of the 26 men in the accident-prone group of this age, 22 fell into the higher nervous classification. It was amongst these men that most of the peptic ulcers occurred.

Threat to Personal Security.—It is impossible to give clinical notes of all the cases examined, but in general it can be said that the stimulus to anxiety in the 25–36 age group was a threat to personal security. One man was under constant suspicion and questioning by the police following the dismissal of his father from the firm for fraudulent conversion ; another, suspected of I.R.A. activities, had been informed that his permit to reside in Northern Ireland was not to be renewed ; another (later sentenced) confided to me that he had been concerned, with others, in a series of " breaking and entering " thefts ; but the most common story was of the shortage of housing, of getting married and " living with the wife's people ", of quarrels with the parents-in-law, most usually the " mother-in-law " (" the old man—he's decent, he understands, but the old woman, she's——! ") was a constantly recurring theme. But whatever the story, the threat, as it appeared to the workman, was almost always directed against his personal security. Financial difficulties were seldom mentioned.

It would appear, therefore, that age is relatively unimportant of itself but that in this age group, 26–35, falls a high incidence of emotional stress. In the case of the larger number living with their parents-in-law, it would appear that all goes well for a few years after marriage. Difficulties with the old people start only when the family begins to increase in number, and after the novelty of the first grandchild has passed.

Lost Time.—Experience has shown that it is not always feasible by ordinary clinical methods to

differentiate between organic illness and vague diagnoses such as " dyspepsia ", " biliousness ", and the like. An attempt was made to do this by clinical examination, together with consultation with the patients' own doctors, who indicated to me the results of hospital investigations. It was by these means that we separated the time lost into the four categories : time lost as the result of (1) accidents, (2) acute illnesses, (3) chronic illnesses, and (4) vague illness or inadequately explained absence.

Newbold (1926) found there was a quite definite positive association between the number of accidents an individual has had and the number of visits made to the Medical Department for minor sickness. She found only a negligible connexion between the total amount of time lost and the incidence of accidents. The experience of this investigation suggests that if only the grossly prone are studied there is a well marked association. This of course is utterly unreliable as a criterion of the amount of sickness or the severity of accidents and no conclusion other than the obvious one can be drawn from my results, *viz.*, that grossly accident-prone people tend to lose more time than others and not necessarily as the result of their accidents. This experience is completely at variance with that of Flanders Dunbar (1943). She found that her accident-prone group had unusually good health records, were seldom off work, and suffered very little from colds or indigestion. It may be that factors were operating in her group which were not present in mine or vice versa but in any event her criteria of accident proneness were less exclusive.

That other factors may be operating is suggested by the report of the Iron and Steel Productivity team which visited the U.S.A. in 1951 (Anglo-American Council on Productivity, 1953). This team noted that there was a discrepancy in the level of lost-time accidents in the two countries, *viz.*, the accident frequency rate in this country was 32·6 per million man/hours worked compared with 7·2 in the U.S.A. iron and steel trades.

Hill and Trist (1953) approached this problem in an interesting way. In a stable work population they classified all absences from work over a four-year period into those which were (*a*) prospectively sanctioned, (*b*) retrospectively sanctioned, and (*c*) unsanctioned. They found that those with the highest number of accidents had also the highest number of unsanctioned absences and that " accidents were negatively associated with that form of absence requiring prospective sanction ".

It should be borne in mind that during their quite prolonged absence from work from all causes the accident-prone were not exposed to risk, and on the assumption that their proneness to accident was unaltered during this period it is probable that had they remained at work they would have incurred even more accidents. In other words, they were probably even more accident-prone than a simple comparison with the control groups would show.

In discussing the finding of Newbold that there is a positive association between the number of accidents sustained by an individual and the number of times he reported sick, Farmer (1932) writes :

> " This relation may in fact be due to a tendency to report both accidents and sickness, which is more marked in some people than in others. On the other hand, it is probable that those who most often report minor sicknesses are in a poorer state of health than others, and so feel the strain of their work more. On account of this they may be more willing to seek relaxation from it by reporting sick."

In view of our finding that there is a considerable amount of emotional instability amongst the accident-prone, it is not unreasonable to suggest that this is partly the reason for their increased tendency to report at the Medical Department, and that their feeling of " unwellness " is psychological in origin. Capel (1944) writes :

> " Anxiety states are manifest by unreasonable fear and anxiety. There is a continuous feeling of anxious expectation, together with a condition of hypersensitivity to noise, lights and other stimuli, and, frequently, sleeplessness. Visceral symptoms are common, being, in many cases, an exaggeration of the normal physiological concomitants of fear. They include such things as palpitation, tachycardia, sweating, precordial pain, shortness of breath, vertigo, nausea, vomiting, variation of appetite, and diarrhoea. It is because of these visceral symptoms that anxiety states are so frequently misdiagnosed as cases of organic disease."

In this connexion the work of Flind and Barber (1945) is relevant. They found that 42% of patients admitted to an R.A.F. special rheumatism centre showed significant psychological disorder. They summarize their discussion as follows :

> " A number of patients complained of pain without lesions disclosed on investigation. In speculating about the nature of the pains complained of by these patients, Halliday (1941) has suggested that they are purely symbolic in nature as expressive of a state of mind and are being consciously or unconsciously used by the patient as a protest against the situation in which he finds himself, or as escape from the obligations which are imposed on him by circumstances. Gordon (1940), on the other hand, states that it is a matter for argument whether the pain is symbolic, that is originating exclusively in the sensorium, or whether the patient is using a mild degree of discomfort, consciously or unconsciously, to achieve an object.
>
> " Ellman, Savage, Wittkower, and Rodger (1942) consider that the inhibition of aggressive elements in the personality of many of these patients may result

in muscular tension felt by the individual as pain and limitation of movement, and erroneously interpreted by the examining doctor as fibrositis.

"The generalized mild aching after a prolonged period of nervous tension is not unknown to many of us, as are also the feelings of fatigue in a similar situation. When the latter, due possibly to some persistent conflict in a predisposed subject, appears too readily and frequently, we have the chief presenting symptom of a neurasthenic state, or fatigue syndrome of psychological origin. In a similar way aching may become readily and frequently induced. On the other hand, another factor, as Gordon (1936) has pointed out, is the possible variation in the individual's threshold for the appreciation of his bodily sensations. It may be that the threshold for the appreciation of such sensations is lowered in some cases of neurosis."

Whatever the explanation it would appear that a certain amount of "rheumatism" is psychogenic and there is a growing body of evidence that many "dyspepsias" have a similar origin (Davies and Wilson, 1937). Tidy (1941) reported that of 2,500 cases admitted to military hospitals for dyspepsia, 35% were diagnosed as "gastritis (functional dyspepsia)". He indicated that as a representation of its frequency this figure is probably fallacious because a smaller proportion of this group than of peptic ulcer find their way to hospital. All the methods of diagnosis available to a modern hospital, including gastroscopy, failed to reveal a lesion. In the discussion which followed there appeared to be a wide measure of agreement that many, if not all, of these cases were psychogenic in origin. It seems, therefore, that much of the time lost by the accident-prone is due to psychological illness masquerading under the guise of organic disease.

Hill and Trist (1953) noted in this respect "that to the extent to which psychological factors were operating (in sick absences) it was expected that absence due to sickness would be associated with that due to accidents. Such an association was shown to exist". These workers suggest that accidents and sickness may be forms of motivated absence—however unconscious the motivation. On the other hand it is recognized that there are certain accident-prone individuals whose reaction to social stresses is quite different—those who make no complaint of symptoms but who tend to become introspective.

Silverman (1945), discussing the importance of the psychological factor in accident proneness, states:

"There are certain individuals who withdraw, so to speak, from the difficulties of life. They become very shy, timid, and seclusive. They cannot accept responsibility and tend to make excuses for not meeting the requirements of the job. They are individuals who have a tendency to daydream exclusively in order to pretend that they are obtaining the satisfaction which they are unable to get in real life. While daydreaming is a relatively normal phenomenon, particularly in young people, it is essentially a characteristic of adolescence and if indulged in excessively beyond this period of life it has an unwholesome effect. Where a worker continued to resort to daydreaming he usually manifests poor self-control and is more readily involved in accidents. His mind is not on what he is doing and he is therefore accident prone."

Again this type of individual has been recognized and, while he often has accidents, he does not fit into the picture of gross accident proneness which came to light in this survey. In a factory where there is continuous repetitive work and therefore opportunities for daydreaming, the picture of the accident-prone individual may be quite a different one.

Organic Illness.—Until Flanders Dunbar (1943) suggested otherwise it has been almost an article of faith that ill health is associated with an increased accident frequency. Many observers have noticed and commented on the association and my own results tend to confirm it. It is not difficult to visualize how toxic and degenerative diseases may adversely affect perceptual or cognitive ability on the one hand and motor control and coordination on the other. It is easy, too, to understand how a relatively minor infection, such as the common cold, can increase accident liability, but the accurate study of the importance of acute illness is difficult because of the variability of the reaction to the illness. One man with boils may remain at work, exposed to accident risks; another with the same degree of infection may go home and be immune. There are other considerations which, while obvious now, only became clear during the course of this investigation.

It seems more profitable to consider observations which have not previously been recorded in the literature: *viz.*, the greater tendency of the accident-prone (*a*) to have peptic ulceration, (*b*) to exhibit transient albuminuria under emotional stress, and (*c*) under the same emotional stress to excrete sweat with a distribution limited to the palms of the hands, soles of the feet, and, less often, the axillae.

(*a*) Thirteen of the 87 accident-prone (15·6%) during the year under review, compared with two out of 100 controls had active peptic ulceration. Some said that they had had ulcers in the past, and some have since developed ulceration, but if they were not proved to have an active lesion during the period studied, by test meal and radiological evidence or by perforation, they are not included. If all who claimed a history of duodenal ulceration were included, the ratio of 7 : 1 would be greatly exceeded.

In discussion of the relationship of their ulceration to their high degree of accident proneness, these men almost invariably connected their discomfort and pain with an inability to concentrate on the job in hand. This is a perfectly reasonable attitude to adopt, and one has seen too frequently men coming for the dressing of a fresh wound complaining, before they leave the department, of some other painful condition, *e.g.*, toothache due to a dental exposure, not to realize that a constant ache or pain affects industrial efficiency. At the same time one cannot help feeling, after listening to the stories of these men, that either their threshold for pain is lowered or that some other factor is involved, or both. It seems significant that all the men who had peptic ulceration and who were also accident-prone should also be classified high in Culpin's grouping. Over 100 years ago it was postulated that gastric changes may be local manifestations of a disturbed nervous system. Clinicians are ready to accept a neurogenic or psychogenic basis for dyspepsia where no structural change in the intestinal canal can be shown, but many are still less than ready to accept such an explanation for a lesion, which can be readily demonstrated.

Harvey Cushing, however, in 1932 described how, after operating on three cases of tumours in the hypothalamic region, each patient died within a short time of peritonitis following perforation, in the first case of the stomach, in the second of the duodenum, and in the third of the oesophagus. Since he published his work, the association of perforating lesions of the upper alimentary tract with operations in the region of the brain-stem has been clearly recognized. Even before this, however, it was known, and has amply been confirmed by numerous experimenters since, that stimulations of the hypothalamus of animals can cause peptic ulceration. In 1934 Beattie and Sheehan were able to produce ulceration by stimulation of the tuberal region of the hypothalamus provided that the vagi were intact, and later from stimulation of the vagi alone. The evidence, therefore, is in favour of the view that at any rate certain peptic ulcerations may be the result of an abnormal parasympathetic stimulus. Cushing (1932) suggests that as

> " the result of spasmodic contraction of its muscular coat, possibly supplemented by local spasm of terminal blood vessels, small areas of ischaemia or haemorrhagic infarct are produced, leaving the overlying mucosa exposed to the digestive effects of its own hyperacid juices ".

Riddoch (1938) concludes as follows :

> " As to the well recognised liability of worrying subjects to gastric and duodenal dyspepsias, the close linkage between emotional and vegetative reactions has long been known, and the intimate anatomical connection of their central neural basis in the diencephalon has now been proven."

Davies and Wilson (1937) enquired into 205 cases of peptic ulcer, and found that in 84% the symptoms began soon after some event affecting the patient's work, or finances, or the health of his family. Only 22% of a control series with herniae gave a history of any such event preceding their illness. They found, as was mentioned earlier, that a group of 100 ulcer patients, using Culpin's system of scoring, had a significantly high score and showed undue nervous tension long antedating their ulcer symptoms. They conclude that chronic peptic ulcer is an example of the influence of the mind in producing structural change.

Sir William Osler, in 1902, when giving an address before the St. Louis Medical Society (included in *An Alabama Student* as " A Backwoods Physiologist ") told the story of how a young American Army surgeon, by name Beaumont, for years cared for a young French Canadian, Alexis St. Martin, who, following a severe gunshot wound developed a huge gastric fistula. In return for this attention Beaumont was allowed to make observations on the patient's gastric secretions. Amongst the many observations made was that of the " profound influence of mental disturbances on the secretion of the gastric juice and on digestion ". Wolff (1943) has reported on a similar patient that fear and dejection produced pallor of the mucosa with diminished acidity, motility, and response to food. Anxiety and hostility produced hyperaemia with increased acidity and motility. During a fortnight of financial anxiety he noticed that the mucosa was unduly susceptible to the production of erosions by trivial injury. Crohn (1942) states that, " Recurrent psychic trauma may either initiate ulceration or maintain activity in an ulcer already formed." He identified the hypothalamus as not only the coordinating centre for the emotions, but as the dominating centre of the autonomic system, thus controlling the secretion, motility, and vasomotor activity of the alimentary canal. He then proceeds to incriminate the cerebral cortex from which recurrent emotional disturbances emanate and pass to the hypothalamus.

Samson Wright (1952) states that stimulation of the middle nuclei of the hypothalamus produces parasympathetic overaction, *e.g.*, cardiac slowing, increased gastric secretion and motility, and even haemorrhagic lesions of the oesophagus, stomach, or duodenum, leading to fatal perforation.

Draper, Dupertuis, and Caughey (1944) have shown that there is a statistically significant length-

ening in the average P – R interval between men who have peptic ulcer and a control group taken at random. If this is true it would seem to be additional evidence in favour of an association between hypothalamic influence and peptic ulceration.

Now we know that psychic disturbances are commonly seen in patients with lesions involving the hypothalamus. Ranson and Magoun (1939) state :

> " With tumours in this region there are frequently seen manic conditions, euphoric states, lively speech, flight of ideas, inclination towards obscenity, untroubled passing off of difficulties with witty references, lively inclinations to move about and occupy oneself, anger accompanied by rude insults and violence of sudden onset and abrupt disappearance."

The main difficulty in interpreting these symptoms is to know whether the lesion is destructive or irritative of the centres involved at the actual time they were being affected. We do know, however, that stimulation of the hypothalamus of experimental animals or the freeing of it from cortical influence causes excitement, and removal of the caudal part of the hypothalamus is necessary to eliminate this excitement. In Korsakoff's syndrome the chief lesions have been found to lie in the hypothalamus, and alterations in personality have resulted from epidemic encephalitis, especially in children. Clinical and experimental evidence both establish that the hypothalamus is the main subcortical integrating central mechanism of the autonomic system, and that it is in some way intimately concerned with the coordination of emotional reactions. It would appear, then, that the relationship of duodenal ulceration with emotional instability may be through the hypothalamus, and as accident proneness, in a certain group at least, is related to both, it, too, may be associated with a condition of the diencephalon, or those parts of the cerebrum or cortico-hypothalamic tracts which influence it.

Albuminuria.—It has been shown that in the special series of examinations of the 87 men involved in this investigation, 52% of the accident-prone, as compared with 7% of the controls, exhibited at least a trace of albumin in the urine. That this albuminuria was transient and benign was proved in each case by clinical examination to exclude nephritis and hypertension, and by the microscopic examination and testing of two further specimens, one passed in the morning before rising, and the other shortly before the end of the day shift. The presence of an occasional hyaline cast was not regarded as pathological. It was highly improbable that the albuminuria was what is called physiological, *i.e.*, following heavy exercise, because in the aircraft industry there is little heavy labour. Nor could it have been due to exposure to cold for the factory was adequately heated. Fever and gross circulatory failure were also excluded as causes by clinical examination.

Forty-seven out of 52 of these men were below the age of 35 years, and, most significantly, over 90% of those in the accident group, or 85% of all who exhibited the sign, were in the upper of Culpin's groups (Table 7). It must be remembered that when this series of specimens was obtained the men were under some degree of emotional stress.

The variability in the statistics given for the incidence of the condition, even when large numbers of men are examined, is illuminating in itself. Lyall (1941) found it only in 0·55% among 20,000 young adults entering the Forces, but the figure given by Diehl and McKinlay (1942) for a large group of male students is ten times higher. It would seem, therefore, that the circumstances under which urine was excreted may be of some importance.

Various explanations have been given to account for the phenomenon—dietetic and postural—but it is difficult to accept these as explaining all cases. One has seen this condition frequently in adolescents at school, when they come to the sick bay complaining of headache and seeking to be excused attendance at certain classes for which, enquiry showed, their homework had not been prepared. Attempts to produce it at other times failed, unless one adopted a harsh and intimidating manner. It is difficult to disassociate, in nervous individuals, an emotional response from the results of any manoeuvre to which they may be subjected. The description given by Price (1945) is that " the subject is often an anaemic, weedy youth, with a dull, heavy aspect and a tendency to fainting. The heart is irritable and the blood pressure unstable and fluctuates with change in posture ". Here we have a picture of vasomotor instability such as one associates with emotional subjects. Ahronheim (1944) noticed that young airmen between the ages of 17 and 26 who fainted following venepuncture almost invariably had a cloud of albumin in the urine, although previous examination had revealed none. In a series of 1,000 consecutive cases he examined the urine before and after venepuncture. He found that more than half of the men had albumin in the second or both specimens, and after detailed consideration of the other causes he comes to the conclusion that the prime factor in the causation of benign or transient albuminuria is not orthostatic or mechanical but emotional. It is, of course, surprising that such a high percentage of healthy

young men should exhibit the sign following such a minor psychic trauma as venepuncture. My figure of 52% was obtained as the result of examining those known to be psychologically poorly adjusted.

It would appear that to explain most readily the relationship of emotional activity and albuminuria we must again turn to the region of the hypothalamus. It has been shown that exposure to cold causes vasoconstriction of the renal blood vessels, which, in turn, results in the appearance of albumin in the urine. Constriction of these vessels as a part of a general vasoconstrictor response may be caused by stimulation of the hypothalamus. This organ, in man, is affected also by emotional activity, and it may thus give rise to the sign. The " small arteries that supply the hypothalamus take origin directly from the circle of Willis " (Ranson and Magoun, 1939). Spontaneous subarachnoid haemorrhage as the result of aneurysm of the circle of Willis is often accompanied by a massive transient albuminuria. In the absence of an authoritative pronouncement, it is not unreasonable to assume that the albuminuria may be the result either of interference with the blood supply of the hypothalamus or of mechanical stimulation by the haemorrhage of the autonomic tracts as they pass from the midbrain.

Disturbances of Bladder Function.—Reference has previously been made to the frequency amongst the accident-prone of two symptoms : (1) The inability to pass urine when requested to do so, and (2) the desire (often with urgency) to micturate. The former is apparently due to spasm of the sphincter vesicae or inhibition of the detrussor muscle—in either case a sympathetic effect ; the latter due to spasm of the bladder—a parasympathetic effect. This second is easily provoked in experimental animals by stimulating the posterior nucleus of the hypothalamus. That the accident-prone very much more frequently than the controls exhibited one or other of these symptoms may be of some diagnostic importance. The polyuria associated with emotional stress is frequently assumed to be a diuresis. That this is not so has been demonstrated by the work of O'Connor and Verney (1942, 1945). They have actually shown that there is an inhibition of diuresis in the dog in these circumstances. Two types were distinguished : (1) a rapid inhibition due to vasoconstriction in the kidney during emotion ; and (2) a slow type due to release of anti-diuretic substance from the neurohypophysis, almost completely abolished by removal of the posterior lobe of the pituitary gland. After denervation of kidneys and suprarenals the slow type occurred consistently in all tests and in all animals but the rapid did not. This phenomenon was observed so constantly that it is actually now being used as one measure of the activity of the hypothalamico-hypophyseal system. The same authors (1946) identify the supra-optico-hypophyseal tract as being the one along which emotional stimuli affect the neurohypophysis.

To stress the importance of the hypothalamus as a subcortical emotional centre expressing itself through the autonomic nervous system is not the purpose of this paper, but the understanding of the relationships of the various observations made in the course of this investigation is found most readily by reference to that small mass of nervous tissue.

Sweating.—The recognition of emotional sweating confined chiefly to the palms and soles has long been made—even by the laity. Associated with it are the cold, clammy hands and feet. The expression " cold feet " is directed in certain strata of society to the timid and fearful as a term of opprobrium. That its presence is *prima facie* evidence of a recognizable degree of emotional tension is part of our thesis. If one is to judge by the paucity of literature, little interest in the subject has been taken outside Japan. Osborne and Cowen (1945) had the opportunity of observing the incidence of " trench feet " (or, as they prefer to call it, " peripheral vasoneuropathy after chilling ") in two groups of men fighting under the same wintry conditions in the invasion of Europe. Group A was made up of unselected infantry men : Group B was composed of psychologically selected men for an armoured formation. In general, the men in Group A developed " trench feet ", the men in Group B did not.

> " The clinical findings suggested that the man prone to psychoneurosis developed a more severe peripheral vasoneuropathy than the man of sound personality and good morale, under equal conditions of exposure to the elements and with the same lack of opportunity for adequate foot hygiene."
>
> In their summary they write :
>
> " It was observed that a history of sweaty hands and feet and a tendency to neurosis were common among soldiers suffering from peripheral vasoneuropathy after exposure to severe cold."
>
> " The findings (of psychiatric examination) suggest that the severity of the foot lesions is related to psychosomatic factors, the man of unstable personality being particularly liable to severe effects from cold. The unstable pre-neurotic has an unstable vasomotor system, and the hypersensitive neuromuscular control of his arterioles may make these vessels more susceptible to trauma from cold." . . . . " such skin, already ' cold and clammy ' must be at a disadvantage when exposed to external chill and dampness."

I am not attempting to suggest that the moistness of the hands of the accident-prone is of itself a

factor in accident proneness. Rather do I take the view that the sweating of the " perspiratory personality " of Osborne and Cowen is symptomatic only.

Clark, Beattie, Riddoch, and Dott (1938), quote the work of Hasama (1930) as follows :

> " Hasama considers that there are two kinds of sweat. The ' cold sweat ' which appears when the skin vessels are constricted under severe emotional disturbances due to fright or fear he regards as ' sympathetic ' in nature. On the other hand, the ' warm sweat ' which appears with vasodilatation and can be abolished by atropine is parasympathetic in its nature. The sweat glands have thus a dual innervation corresponding closely to that which has been demonstrated for the salivary glands."

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> " active sweat glands are present most densely on the sole, forehead, and palm, somewhat less on the back of the hand, still less on the lumbar region, axillae and the lateral and extensor surfaces of the extremities, and least on the trunk and the flexors and medial surfaces of the extremities ".
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> He shows that " sweating caused by heating inevitably appears all over the body surface and never locally, even when the heat is confined to a small portion of the skin surface, but the palms of the hands and soles of the feet do not conform to this general rule. These parts are those where sweat glands are present most densely, and our experiments proved that in the state of so-called insensible perspiration the amount of water discharged from the skin was distinctly larger at those parts than at any other parts of the body surface. It is peculiar, however, that the perspiration from these parts does not increase at all from ordinary thermal causes ; in other words, the palms and soles do not sweat under high atmospheric temperature which causes a profuse sweating on all remaining parts of the body surface. . . . The most adequate cause for this sweating seems, however, to be mental stress ".

Lovatt Evans (1945) states :

> " The lower centres for heat loss must be placed in the medulla and cord, at any rate so far as concerns control of heat loss by alterations in the blood supply to the skin, or by the secretion of sweat. The same is true for heat production arrangements, such as shivering, vasoconstriction, metabolic changes, etc. But these lower centres can only function in a coordinated manner when under the higher control of the hypothalamus."

It would appear that sweating from thermal causes is a reflex act not necessarily involving the higher centres in the nervous system, but that emotional sweating is initiated directly by the hypothalamus as the result of impulses from the cortex.

Why should the palms of the hands and the soles of the feet sweat during emotional stimulus ? Kuno suggests that as in most languages there is a phrase for " spitting on the hands "—an act which often, even in this country, precedes the grasping of an implement, there is a recognition that the additional moisture increases the friction between the hand and the implement. In an emergency (presided over by the hypothalamus) nature supplies this localized moisture by sweating. The value of this physiological response to a threat against one's security would probably have been appreciated more keenly in an earlier stage in the history of our race. Whatever the reason for its presence it is certainly associated as a sign in those accident-prone who have a tendency to neurosis, and who occasionally exhibit a transient albuminuria. A glance at the mechanism of the control leads us to the same meeting place to which we were led by some of our other findings—the hypothalamus.

Ranson and Magoun (1939), in reviewing the work of recent years on this small organ, quote more than 300 different references, many of which appear to contradict quite flatly what has only recently been considered as established fact. It is quite clear that the hypothalamus, to use a phrase of R. L. Stevenson in another context, " is a city not yet habitable by the mind of man ". It is generally accepted, however, that it is

> " concerned with the integrated control of both the sympathetic and parasympathetic system and the secretion of the posterior lobe (neural division) of the pituitary. It is probably concerned to an important extent with reflex emotional expression and in these reactions it influences the activity of appropriate groups of skeletal muscles " (Samson Wright, 1952).

Biggart (1944), after reviewing the function of this region of the brain with regard to water metabolism, fat metabolism, carbohydrate metabolism, its role in disorders of sex, in temperature regulation, in sleep rhythm, and finally as an occasional factor in the production of peptic ulceration, concludes as follows :

> " It will be apparent that the hypothalamus serves as an integrating and coordinating mechanism for many of the functions of the body which are mediated by way of the autonomic nervous or endocrine systems. Often it appears that there is a pressor balanced by a depressor mechanism, and that, in general, one of these tends to be situated in the anterior, the other in the posterior, hypothalamus. This balance is so delicately preserved that we are unaware of its existence, and it is only in disease that the manifold functions of this area have been manifested. The stability of body temperature, the control of body fat, the beautiful balance of the intake and output of water, the respiratory rhythm, the constancy of the heart-beat, the cycle of sleep,

the balance between emotionalism and excessive placidity, the control of sex—all these go to create a fixity of the internal environment of the body, and are integrated, coordinated and maintained by the nervous activities of this region."

That abnormalities of some of these functions commonly occur in psychoneurotic patients is well known, and one wonders whether, in these cases, there is either a disorder of the hypothalamus itself or of its control by the cerebral cortex. It would appear that the latter explanation is the more probable. This in itself greatly adds to the difficulty of further study at present, for the reaction of two humans to the same situation may vary—one may blush and another may exhibit pallor, the pulse rate of one may rise, of the other, fall. Bard (1941), states that :

" The cortex, therefore, probably normally exerts both inhibitory and excitatory effects, either directly on the hypothalamus or on the final paths which it has in common with the hypothalamus. In putting emphasis on the hypothalamus as a source of emotional behaviour, it must not be forgotten that the cerebral cortex, whatever its functional relationship to the hypothalamus may be, enormously increases the number of circumstances which are capable of acting as emotional stimuli."

Conclusion

Our discussion has centred largely around the hypothalamus and it may be well to consider why this is so. We have seen that the accident-prone are socially maladjusted, that they lose time as a result of complaints which at present are not recognized as having an organic basis, and that under the influence of a relatively minor emotional stimulus they tend to perspire freely on the hands and feet, and, less frequently, to exhibit albuminuria. In addition a significant proportion have peptic ulceration.

It has been shown that disorders of behaviour result from lesions of the hypothalamus. The nature of these disorders is, in some respects, akin to those shown on occasions of uncontrolled anger by the apparently normal. They are not unlike those exhibited in the decorticated animal. It is suggested that the exaggerated emotional response of the psychoneurotic may be due either to stimulation of the hypothalamus by impulses from the cortex, or to a diminution of the inhibitory impulses from that area. We know, too, that the accident-prone complain of symptoms which appear to have no pathology in the organ to which they are attributed. Further, it is now realized that most of these symptoms are really the result of a loss of balance between the sympathetic and parasympathetic systems influenced by abnormal emotional activity, and mediated by the hypothalamic region of the brain. That the localized sweating confined mainly to the hands and feet is emotional in causation is recognized, and that its control is in the diencephalon has been acknowledged. Similarly, local vasomotor instability of the renal vessels, which is the probable cause of the appearance of albumin in the urine, is part of a general vasomotor reaction controlled by the hypothalamus. Finally, lesions in this region have been shown to be associated with peptic ulceration.

We have travelled a long way from the lad at the bench who repeatedly comes for a simple dressing to his wound, but we return. Why does he get these wounds? The psychologist believes that the reason is not carelessness, nor is it chance, but rather a state of mind. Miles and Eyre (1922) recognized three different types of attitude to accidents : (1) the victim felt as if the event were apart from him, (2) he " knew it was going to happen but felt powerless to prevent it ", and (3) the victim felt his mind went momentarily blank. Smith (1943), commenting on these, states : " In all these descriptions there is a recognition after the event of a mental failure to control the situation."

This observation does not entirely explain the mechanism of failure but recent work on " The Relation of Adrenalin to Acetylcholine in the Nervous System " reviewed by Burn (1945) may take us a step further. It is stated that :

" Low concentrations of adrenalin in the nervous system increase the stimulant action of small doses of acetylcholine and higher concentrations of adrenalin antagonise them. These two actions may be seen as two phases in the effect of a single dose. Adrenalin, either injected or liberated by adrenergic nerves, also has various actions on voluntary muscles and nerves. It increases the action of acetylcholine on denervated muscles and it improves neuromuscular transmission when this is diminished by fatigue. It actually improves transmission along the trunk of a nerve. The transmission, however, may be depressed by maximal doses of adrenalin or by stimulation of the sympathetic system. This depression, occurring as it does after sympathetic stimulation, is possibly the physiological change underlying the condition in which an animal is paralysed by fear."

At the conclusion of his review he writes :

" If the action of acetylcholine in the central nervous system, including the brain, is indeed modified by adrenalin, it is conceivable that this modification is the basis of changes in nervous reaction, and even in behaviour, which occur in emotional states when an abnormal concentration of adrenalin is present."

One cannot resist suggesting that as the accident-prone appear, in the main, to be emotionally unstable, and as the evidence directs our attention to the centre of the autonomic system, the hypothalamus, that under the influence of stimulatory

factor in accident proneness. Rather do I take the view that the sweating of the " perspiratory personality " of Osborne and Cowen is symptomatic only.

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the balance between emotionalism and excessive placidity, the control of sex—all these go to create a fixity of the internal environment of the body, and are integrated, coordinated and maintained by the nervous activities of this region."

That abnormalities of some of these functions commonly occur in psychoneurotic patients is well known, and one wonders whether, in these cases, there is either a disorder of the hypothalamus itself or of its control by the cerebral cortex. It would appear that the latter explanation is the more probable. This in itself greatly adds to the difficulty of further study at present, for the reaction of two humans to the same situation may vary—one may blush and another may exhibit pallor, the pulse rate of one may rise, of the other, fall. Bard (1941), states that :

" The cortex, therefore, probably normally exerts both inhibitory and excitatory effects, either directly on the hypothalamus or on the final paths which it has in common with the hypothalamus. In putting emphasis on the hypothalamus as a source of emotional behaviour, it must not be forgotten that the cerebral cortex, whatever its functional relationship to the hypothalamus may be, enormously increases the number of circumstances which are capable of acting as emotional stimuli."

Conclusion

Our discussion has centred largely around the hypothalamus and it may be well to consider why this is so. We have seen that the accident-prone are socially maladjusted, that they lose time as a result of complaints which at present are not recognized as having an organic basis, and that under the influence of a relatively minor emotional stimulus they tend to perspire freely on the hands and feet, and, less frequently, to exhibit albuminuria. In addition a significant proportion have peptic ulceration.

It has been shown that disorders of behaviour result from lesions of the hypothalamus. The nature of these disorders is, in some respects, akin to those shown on occasions of uncontrolled anger by the apparently normal. They are not unlike those exhibited in the decorticated animal. It is suggested that the exaggerated emotional response of the psychoneurotic may be due either to stimulation of the hypothalamus by impulses from the cortex, or to a diminution of the inhibitory impulses from that area. We know, too, that the accident-prone complain of symptoms which appear to have no pathology in the organ to which they are attributed. Further, it is now realized that most of these symptoms are really the result of a loss of balance between the sympathetic and parasympathetic systems influenced by abnormal emotional activity, and mediated by the hypothalamic region of the brain. That the localized sweating confined mainly to the hands and feet is emotional in causation is recognized, and that its control is in the diencephalon has been acknowledged. Similarly, local vasomotor instability of the renal vessels, which is the probable cause of the appearance of albumin in the urine, is part of a general vasomotor reaction controlled by the hypothalamus. Finally, lesions in this region have been shown to be associated with peptic ulceration.

We have travelled a long way from the lad at the bench who repeatedly comes for a simple dressing to his wound, but we return. Why does he get these wounds ? The psychologist believes that the reason is not carelessness, nor is it chance, but rather a state of mind. Miles and Eyre (1922) recognized three different types of attitude to accidents : (1) the victim felt as if the event were apart from him, (2) he " knew it was going to happen but felt powerless to prevent it ", and (3) the victim felt his mind went momentarily blank. Smith (1943), commenting on these, states : " In all these descriptions there is a recognition after the event of a mental failure to control the situation."

This observation does not entirely explain the mechanism of failure but recent work on " The Relation of Adrenalin to Acetylcholine in the Nervous System " reviewed by Burn (1945) may take us a step further. It is stated that :

" Low concentrations of adrenalin in the nervous system increase the stimulant action of small doses of acetylcholine and higher concentrations of adrenalin antagonise them. These two actions may be seen as two phases in the effect of a single dose. Adrenalin, either injected or liberated by adrenergic nerves, also has various actions on voluntary muscles and nerves. It increases the action of acetylcholine on denervated muscles and it improves neuromuscular transmission when this is diminished by fatigue. It actually improves transmission along the trunk of a nerve. The transmission, however, may be depressed by maximal doses of adrenalin or by stimulation of the sympathetic system. This depression, occurring as it does after sympathetic stimulation, is possibly the physiological change underlying the condition in which an animal is paralysed by fear."

At the conclusion of his review he writes :

" If the action of acetylcholine in the central nervous system, including the brain, is indeed modified by adrenalin, it is conceivable that this modification is the basis of changes in nervous reaction, and even in behaviour, which occur in emotional states when an abnormal concentration of adrenalin is present."

One cannot resist suggesting that as the accident-prone appear, in the main, to be emotionally unstable, and as the evidence directs our attention to the centre of the autonomic system, the hypothalamus, that under the influence of stimulatory

and inhibitory impulses from the cerebral cortex, minor imbalances of adrenalin and acetylcholine result. A small overflow of adrenalin might cause not "paralysis by fear" but paresis by anxiety, which, in turn, might show as muscular imbalance of central origin. That muscular incoordination under pressure is a feature of those who score high in Culpin's groups has been demonstrated by Culpin and Smith (1930) as the result of submitting them to tests on the McDougall-Schuster dotting machine and the pursuit meter. The mere fact of submitting a nervous subject to a test of any sort is apt to induce an emotional state, even if of only a minor degree, and this would increase as the test becomes more difficult. If conduction in the nervous system is inhibited by an outpouring of adrenalin it would at least appear possible that, as the result of a delay in impulses eventually reaching the neuromuscular junctions, or of a diminution of their number or strength, muscular incoordination would result. The fact that the whole central nervous system would be involved in the process might account for the passivity of the accident-prone at the actual moment the accident takes place.

It might also explain the commonly held view that the obsessional neurotics (whose response is more on the parasympathetic side than on the sympathetic) tend not to have accidents.

In conclusion it should be stated that the results of this investigation would apply only to those engaged on work of a similar nature to that of the aircraft industry. They would not, for example, apply to road accidents where intelligence seems to be a more important factor.

Further, it is not suggested that chance is entirely eliminated in accident causation. It is probable that, by using more involved statistical methods, a larger number of accident-prone would have been identified, but, even so, the number of accidents sustained by those would probably not have been more than 20% of the total. Our considerations have almost entirely been related to grossly accident-prone workers.

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COAL-MINERS' PNEUMOCONIOSIS IN FOUR COLLIERIES IN COUNTY DURHAM

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Aims of the Investigation

Clinical experience (Browne, Beck, and McCallum, 1949) and rising certification figures by the Pneumoconiosis Medical Board show that there is a pneumoconiosis problem amongst Durham coal-miners. Moreover, a study of large films, taken following routine mass miniature radiography (M.M.R.) at eight Durham pits (McCallum, 1952), suggested that at least 3 to 6% of miners at these pits had well marked radiological signs of pneumoconiosis. This was a crude estimate, because the number of volunteers at each pit was never more than 61% of the total number of men employed, and the composition of the sample not radiographed was unknown. It may be that those men not radiographed had a higher proportion of disease than those who were. Furthermore, only full-size chest films taken of the men whose miniature appeared abnormal were studied; an unknown number of cases in the early categories of pneumoconiosis were missed in the viewing of the miniature films. A survey to measure the prevalence of pneumoconiosis in a number of collieries in County Durham therefore seemed necessary.

This paper describes planned surveys in four representative Durham pits in 1950–51, in which an attempt was made to radiograph every man employed above or below ground with a full-size chest film (12 in. × 15 in.). It must be emphasized that only the radiological appearances of pneumoconiosis are dealt with here, and that no detailed attempt is made to relate these to symptoms nor to estimate how much respiratory disability is the result of the changes described. An attempt has, however, been made to relate the radiological picture to whether a man has to change his job to one which is lighter.

Methods

Choice of Pits.—There were several considerations in the choice of suitable pits for these surveys. To take a random sample consisting of many complete collieries in the county is not practicable, since it would produce an impossibly large number of men to be radiographed. It was essential that the collieries should be characteristic of the whole coalfield as far as possible, and that geographical position and degree of mechanization should be taken into account. The coal-mines should not be too big, as the mobile *x*-ray unit which was to be used for this work was only available for short periods, and there had to be a reasonable prospect of examining every man and following up those who did not come forward. Suitable accommodation near the pit head was necessary, and, in order to ensure that there would be a full attendance and that most or all of the men would have worked at the pit for the major part of their working life, a compact community was desirable. Finally, pits which had not previously had a visit from an *x*-ray unit were more likely to give the true prevalence of pneumoconiosis, since many men with this condition would not have already been detected and perhaps advised to change their job, thereby leaving a selected population.

The Collieries Chosen.—Two pits (L,M) were in the western part of the coalfield and two (K,N) in the eastern part where the future development of this coalfield largely lies. The coal in the east of County Durham is beneath a thick layer of rock, while that in the west, in the older part of the field, is not so deep and in the past has been more easily obtained.

In size, these mines varied from 862 men to 1,921 men and it was planned to survey them in

from one to two months each. No previous surveys of this kind had been made and an M.M.R. unit had not visited these pits before, but the number of men from them who had been certified in each year between 1943 and July, 1948, which was before the use of mass radiography in this coalfield, was known (Table 1).

TABLE 1
NO. OF MEN FROM EACH OF FOUR PITS CERTIFIED BY SILICOSIS BOARD FROM 1943 TO JULY, 1948

Pit	No. of Men on Payroll 1950–51	1943	1944	1945	1946	1947	Half 1948	Total
K	1,638	—	2	1	3	3	1	10
L	862	—	—	—	—	—	—	0
M	1,302	—	1	—	1	—	—	2
N	1,921	5	8	8	6	8	15	50

According to the certification figures Pit N, with 50 cases, was by far the worst, and indeed was a notoriously bad pit as regards pneumoconiosis, while Pit L was apparently free from this trouble. Pits K and L were in compact mining communities, but M drew men from villages all round it, " like a clock face " as a union official described it. Pit N was near a large town and its workers were widely scattered.

Organization of the Surveys.—The surveys were carried out with the cooperation of the North Eastern Regional Hospital Board, who gave permission to use the Durham Mass Miniature Radiography Unit ; the National Coal Board with its divisional and area medical officers ; and the National Union of Mineworkers (Durham). A system of appointments was arranged for every man on the pay roll, and a fresh appointment was sent at the end of each day to those who failed to attend.

The purpose of the survey and the importance of a full turn-out of men were explained at public meetings, and any questions from the men were answered.

Before coming for examination men were given a leaflet on which to enter their occupational history in detail from the time of leaving school. In this way each had an opportunity to think about it and perhaps to set it out more accurately, thus saving time when attending for radiography. The information was then entered on another sheet by the clerks of the *x*-ray unit who were experienced in taking such histories, and who asked for further details of certain jobs or queried obvious errors and omissions.

Radiology.—The chest films were taken, using standard mass miniature radiography equipment, in a van with trailer generator. No miniature films were taken, as these have been found unsatisfactory for this type of work (Fletcher, 1953 ; Cochrane, 1951 ; McCallum, 1952 ; Newell and McCallum, 1954). Radiographs of the highest possible quality were sought and the number of recalls for technical faults was small.

Films were categorized by three experienced observers, using the Pneumoconiosis Research Unit method, which is a quantitative radiological classification into four categories of increasing amounts of simple pneumoconiosis (Categories 1–4) and four of progressive massive fibrosis (P.M.F., categories A–D), (Fletcher, Mann, Davies, Cochrane, Gilson, and Hugh-Jones, 1949). If the two most advanced simple categories (3 and 4) are combined into a single category 3, this classification then corresponds to the proposed International Classification of Pneumoconiosis (Cochrane, Davies, and Fletcher, 1951 ; International Labour Office, 1953). Each observer categorized the films on his own and without prior knowledge of any readings already made by other observers or of the occupational history. This allowed each individual to read at his own speed without the influence of the opinion of other, and perhaps stronger, personalities than his own, a possible disadvantage where combined readings are made.

The final category was determined as follows : if all, or two out of the three, readings agreed, then this was the final category ; if all the readings were different, but were consecutive, then the mean reading was the final category ; when they were all different but not consecutive, further readings were made by two of the observers working separately, up to a total of seven readings, and either the simple majority reading or the mean to the nearest whole number of these readings was made the final category. The number of films which it was necessary to read more than three times was only seven in Pit K, 12 in L, seven in M, and 39 in N.

Follow-up of Non-attenders.—A social worker from the Department of Industrial Health paid a visit to every man on the pay roll of each colliery who did not come for a radiograph. A personal appeal and explanation was made, together with an offer of *x*-ray examination either at Newcastle or elsewhere. If the refusal was point-blank or there were good reasons for not attending, such as illness, at least some information was obtained about the man and his occupational history, so that it was possible to assess from this the amount of exposure to dust that he was likely to have had. For example, if he was a young man with no facework he would be unlikely to have pneumoconiosis. On the other

hand, a man of 55 with 30 years of facework might be more likely to have it.

Results

The Response of the Men.—Eighty-nine per cent. of 5,723 coal workers above and below ground at the four Durham collieries were radiographed (Table 2).

TABLE 2
NO.* AND PERCENTAGE OF MEN AT EACH COLLIERY RADIOGRAPHED AT THE SURVEYS

Colliery	Total No. of Men from Pay Record	Men Radiographed		Men not Radiographed
		No.	%	
K	1,638	1,539	94·0	99
L	862	803	93·2	59
M	1,302	1,180	90·6	122
N	1,921	1,596	83·1	325
Total	5,723	5,118	89·4	605

* The total number of men employed at the colliery was obtained from the pay records at the time of the survey.

The highest proportion of men attended at the first two collieries visited, which were the most compact communities and where the *x*-ray unit was nearest the shaft top. The lowest percentage (83%) was at the fourth colliery, where conditions for the work were less satisfactory and the unit some distance away from the shaft.

Prevalence.—The radiological diagnosis of cases of pneumoconiosis, all categories, in these pits varied from 30 to 35% of the men, with an average of 32% (Table 3). If the faceworkers only are

TABLE 3
PERCENTAGE OF EXAMINED MEN WITH PNEUMOCONIOSIS IN EACH COLLIERY BY CATEGORIES

Category	Colliery							
	K		L		M		N	
	No.	%	No.	%	No.	%	No.	%
1	129	8·4	88	10·9	156	13·2	156	9·8
2	175	11·4	76	9·5	120	10·2	185	11·6
3 and 4	119	7·7	68	8·5	79	6·7	182	11·4
P.M.F.	43	2·8	9	1·1	15	1·3	43	2·7
Total	466	30·3	241	30·0	370	31·4	566	35·5

considered, then the average prevalence of pneumoconiosis is 39% at these pits.

In each colliery the proportion of films placed in Categories 1 and 2, between which there is probably most disagreement, does not differ greatly, and it is noteworthy that only a little over 2% of all the men had progressive massive fibrosis with which most disability is associated (Cochrane, Fletcher, Gilson, and Hugh-Jones, 1951).

Twenty-four office workers and other non-mining employees were also included, five each in collieries K, L, and M, and nine in colliery N, so that the results are very slightly diluted by these men not at risk. On the other hand, they provided a useful control of the validity of the radiology. These men, whose average age was 36 years with a range of 15½ to 65 years, were all placed in Category 0 although their occupational histories were not known by the viewers.

The overall results of the surveys in each pit are strikingly similar, especially in Pits K, L, and M. Pit N has more men in Category 3, which may be the result of much dustier conditions, but this pit had relatively more older men with longer exposure to dusty conditions. In age groups 36 to 45 years and 46 to 55 years a third of all the men were in Colliery N (Table 4). If only the very obvious categories of

TABLE 4
NO. AND PERCENTAGE OF ALL MEN RADIOGRAPHED BY COLLIERY AND AGE

Age	Colliery									
	K		L		M		N		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
15–25	333	35·9	181	19·5	183	19·7	230	24·8	927	99·9
26–35	396	32·8	165	13·7	243	20·1	403	33·4	1207	100·0
36–45	337	26·7	196	15·5	304	24·1	425	33·7	1262	100·0
46–55	287	27·5	137	13·1	274	26·3	344	33·0	1042	99·9
56+	186	27·4	124	18·2	176	25·9	194	28·5	680	100·0
	1,539	30·1	803	15·7	1,180	23·1	1,596	31·2	5,118	100·1

pneumoconiosis are considered (Category 3 upwards), 11% of men show radiological changes, a figure approximately double that previously reported from this coalfield.

The amount of progressive massive fibrosis is also very similar in all four pits. The observer error in separating these categories from the simple ones is relatively small, but as they are the most easily recognized and cause most disability, the numbers have probably suffered most from withdrawals due to ill-health, death, or certification.

Nearly all the faceworkers had done at least three-quarters of their facework at the same pits, and it can reasonably be assumed that the lung

TABLE 5
PROPORTION OF FACEWORKERS' YEARS AT THE FACE SPENT AT THEIR PRESENT COLLIERY

Category	Colliery			
	K (%)	L (%)	M (%)	N (%)
0	93·2	76·1	74·1	86·8
1	93·5	78·3	75·5	85·5
2	95·8	81·6	81·0	88·4
3 and 4	98·1	81·4	86·1	89·3
P.M.F.	97·7	73·6	82·8	88·4
	95·1	78·6	77·8	87·6

changes found were the result of the dust in the pits in which they were working when radiographed (Table 5).

Most of the time which the men who were radiographed had spent elsewhere was frequently in a mine or mines in the same area.

Withdrawal from Facework.—Some evidence of the relation between the radiological findings and disability from pneumoconiosis was obtained from an analysis of the withdrawals from facework to non-facework, as shown by the occupational histories. In this report "facework" refers to certain well defined jobs which involve regular exposure to high concentration of mixed dust at or near the coal face and it includes all the men radiographed who have worked for six months or more as a hewer (hand or pneumatic), coal cutter, stoneman, filler, deputy, or shotfirer. Men who had worked for less than six months at these jobs or who had never done them at any time were classed as non-faceworkers. In each colliery the findings were much the same, the percentage of withdrawals increasing with age. When the age of withdrawal of men from facework is set out by categories, it is evident that an increase in simple category is not accompanied by a corresponding increase in the change from facework to non-facework, but that in the group with P.M.F. the percentage of withdrawals rises greatly (Table 6). No information is available of the number of men who have left these collieries altogether, either from age and all causes of ill-health or because no light work was available for them, but there is, in recent years, a tendency for certified pneumoconiosis cases to remain on, as they are usually considered first for light jobs, and this would affect men at the collieries in all categories over 2. In simple pneumoconiosis increasing

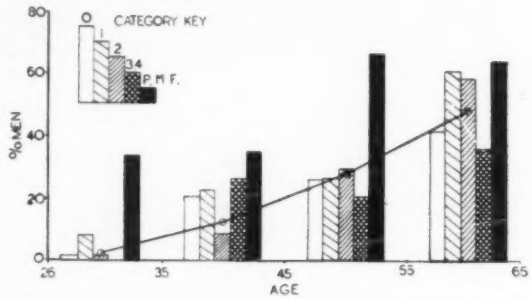

FIG. 1.—The proportion of men who give up coal-facework by age and category. The curve links the averages for each age group.

age rather than increasing category seems to be correlated with change to lighter work and withdrawal from the coal face (Fig. 1). Even in radiological categories 3 and 4 for the two age groups over 46 there were not more withdrawals than in Category 0 for the same age groups. But for all categories there is increasing withdrawal from facework as age rises. In the P.M.F. categories, however, for each age group a higher proportion of men withdraw from the coal face than in any simple category, and the proportion of withdrawals increases by age also, being 33·3% in the decade 26 to 35, but 63·6% at 56 to 65. The advice given to the certified men is an unknown variable, but it is likely that, especially in the complicated categories, a number of men were advised to leave the coal face because of the appearance of their radiographs rather than because they were disabled. Furthermore, progression from simple pneumoconiosis to P.M.F. may occur whether men withdraw from dusty work or remain in it (Davies, Fletcher, Mann, and Stewart, 1949), although recent work suggests that the attack rate of P.M.F is greater in those men with continuing dust exposure (Cochrane, personal

TABLE 6

TOTAL FACEWORKERS, OR FORMER FACEWORKERS, BY AGE AND CATEGORY, SHOWING NUMBER AND PERCENTAGE WITHDRAWN FROM FACEWORK FOR AT LEAST SIX MONTHS AT TIME OF SURVEY BUT STILL EMPLOYED AT THE COLLIERY*

Age		Category											
		0		1		2		3 and 4		P.M.F.		Totals	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
26–35	Faceworkers	558		88		63		23		3		735	
	Withdrawn	9	1·6	7	8·0	1	1·6	—	—	1	33·3	18	2·4
36–45	Faceworkers	431		161		198		156		26		972	
	Withdrawn	46	10·7	20	12·4	17	8·6	25	16·0	9	34·6	117	12·0
46–55	Faceworkers	315		126		172		172		47		832	
	Withdrawn	81	25·7	33	26·2	50	29·1	35	20·3	31	66·0	230	27·6
56–65	Faceworkers	227		91		105		95		33		551	
	Withdrawn	93	41·0	55	60·4	61	58·1	34	35·8	21	63·6	264	47·9

* No information is available concerning men who have left the pit altogether or have been unable to get work at the pit.

TABLE 7
NO. AND PERCENTAGE OF MEN IN EACH RADIOLOGICAL CATEGORY BY AGE*

Age in Years	Radiological Category										Total	% in Category 1 and Over	% in Category 2 and Over
	0		1		2		3 and 4		P.M.F.				
	No.	%	No.	%	No.	%	No.	%	No.	%			
15–25	909	98·1	17	1·8	1	0·1	—	—	—	—	927	1·9	0·1
26–35	1,018	84·3	98	8·1	65	5·4	23	1·9	3	0·2	1,207	15·7	7·5
36–45	701	55·5	173	13·7	204	16·2	157	12·4	27	2·1	1,262	44·5	30·7
46–55	507	48·7	139	13·3	177	17·0	172	16·5	47	4·5	1,042	51·3	38·0
56+	340	50·0	102	15·0	109	16·0	96	14·1	33	4·9	680	50·0	35·0
Total	3,475	67·9	529	10·3	556	10·9	448	8·8	110	2·1	5,118	32·1	21·8

* Categories 3 and 4 have been combined, also all categories of P.M.F.

communication), so that the number of men with P.M.F. amongst those who have withdrawn from facework may be augmented to some extent by the development of P.M.F. in men who left facework with simple pneumoconiosis.

Increasing Age.—If the men are grouped by age and radiological category in the Pneumoconiosis Research Unit classification (Fletcher and others, 1949), it is found that as age increases the proportion of men in each category of pneumoconiosis increases until 36 to 45 and then stabilizes (Table 7).

Between 26 and 35 years nearly 16% of the men have pneumoconiosis of Category 1 and over, or if Category 1 is excluded, 7·5% of the men. Between 36 and 45 years of age the proportion rises to 44·5% for all categories, or nearly 31% without Category 1, so that whether Category 1 or 2 is taken as the lowest recognizable level the sharp increase over the age of 35 years remains. The same change occurs quite distinctly in each colliery (Table 8), and further emphasizes the marked similarity in the results of the surveys in these four geographically widely separated pits in Durham.

TABLE 8
MEN WITH PNEUMOCONIOSIS (CATEGORY 1 AND ABOVE) IN EACH COLLIERY BY AGE

Age	Colliery									
	K		L		M		N		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
15–25	6	2	6	3	4	2	2	1	18	1·9
26–35	69	17	24	15	26	11	70	17	189	15·7
36–45	158	47	77	39	119	39	207	49	561	44·5
46–55	150	52	66	48	129	47	190	55	535	51·3
56+	83	45	68	55	92	52	97	50	340	50·0

After 35 years of age the proportion of men with pneumoconiosis in each 10-year group remains much the same until the age of 55 when there is a slight fall, but the number of men in this group is only about half of those in each of the preceding three groups.

Years at Facework.—The men have been divided into those who have done facework and those who have not, on the basis of their occupational histories, rather than making a distinction between surface and underground workers. Underground workers may be at some distance from the face and their dust exposure low or intermittent, while many men in surface jobs have spent a period at facework and have changed to the surface because of disability from a variety of causes, including pneumoconiosis. What is important in the occupational history is not what a man is doing when the radiograph is taken but what the pattern of his history has been for the whole of its length.

In Table 9 and Fig. 2 the men are grouped by radiological categories and number of years spent at facework. It is notable that only 1% of the non-

TABLE 9
NO. AND PERCENTAGE OF MEN IN EACH RADIOLOGICAL CATEGORY BY YEARS AT FACEWORK*

No. of Years at Face	Radiological Category										Total	% in Category 1 and Over	% in Category 2 and Over
	0		1		2		3 and 4		P.M.F.				
	No.	%	No.	%	No.	%	No.	%	No.	%			
0	1,811	96·0	55	2·9	17	0·9	2	0·1	1	0·1	1,886	4·0	1·1
1–10	924	75·3	155	12·6	100	8·1	43	3·5	5	0·4	1,227	24·7	12·1
11–20	341	40·4	145	17·2	185	21·9	139	16·4	35	4·1	845	59·6	42·5
21–30	237	34·1	97	14·0	153	22·0	170	24·5	37	5·3	694	65·9	51·9
31+	162	34·8	77	16·5	101	21·7	94	20·2	32	6·9	466	65·2	48·7
Total	3,475		529		556		448		110		5,118		

* Categories 3 and 4 have been combined, also all categories of P.M.F.

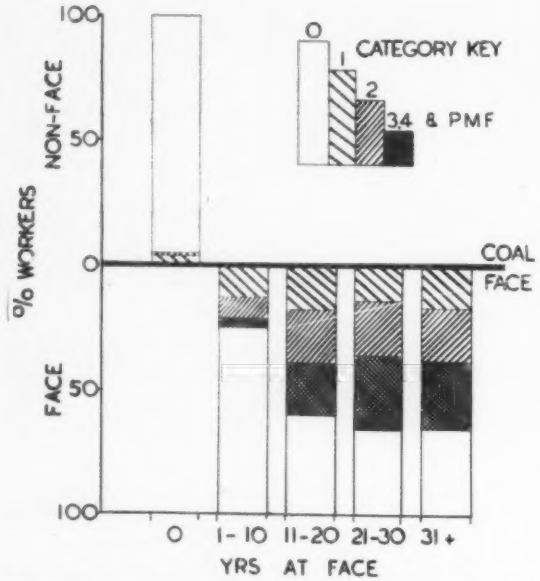

FIG. 2.—The proportion of men with pneumoconiosis related to years at the coal face.

faceworkers shows changes of Category 2 or more and that there was only one man with P.M.F.

This small proportion of non-faceworkers with early pneumoconiosis is probably made up of men whose dust exposure has nevertheless been high, or men with a high susceptibility to dust retention. Of the 75 non-faceworkers with pneumoconiosis, 46 worked at the same time as datal workers (labouring underground) or on haulage work underground, often for long periods. Of 29 men who had never worked underground at all, 11 had worked as coal screeners and nine as blacksmiths at some time.

After one to 10 years at the face 12% of the faceworkers are in Category 2 or more, but this figure is nearly quadrupled after 11 to 20 years at the face. About 10 years at facework appears to be a crucial point, after which the main effect of the dust becomes marked, corresponding to the rise after the age of 35 years (Table 7). The proportion of men in each category tends to remain at the same level after a certain period of time; for example, in Category 1 the proportion reaches about 16% after eight years' facework, in Category 2 it reaches 22% after 13 years, and after about 23 years Category 3 and the complicated categories together remain at 29% of the men.

The most striking feature of Table 9 is that after 20 years at the face half the men have radiological pneumoconiosis of Category 2 or more, and nearly 30% have well marked changes of Category 3 and/or progressive massive fibrosis. After about 30 years at the face there is a slight drop in the proportion of men with pneumoconiosis, but the numbers are smaller though the difference is not so great as in the men over 55 in Table 7.

When the collieries are considered separately the results in each are again remarkably similar (Table 10).

TABLE 10
PERCENTAGE OF PNEUMOCONIOSIS (CATEGORY 1 AND ABOVE) BY COLLIERIES

Years at Face	Colliery				Average
	K	L	M	N	
0	3	5	6	3	4·0
1–10	31	21	16	26	24·7
11–20	42	62	56	62	59·6
21–30	71	63	65	65	65·9
31–	61	66	62	72	65·2

Age and Facework Together.—The effect of age and facework together is shown in Table 11, in which the data for Category 2 or more are combined. If the apparent effect of age alone upon the appearances of pneumoconiosis be considered, it can be seen that for men who have never been on the coal face there is a rise from 0·4% at ages 26 to 35 to 2·8% 10 years later, but the proportion of pneumoconiotics then remains constant. For the men who have spent one to 10 years at the coal face there is a rise with age to 19% at 36 to 45 years, and then a gradual fall. At 11 to 20 face-years there is a rise which is about twice as steep from age 26 to 45, followed by a steeper fall. For the next two decennial

TABLE 11
MEN BY AGE AND YEARS OF FACEWORK WITH PNEUMOCONIOSIS OF CATEGORY 2 OR MORE

Age	Years at the Face											
	0		1–10		11–20		21–30		31 and Over		Average	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
15–25	0	—	1	0·7	—	—	—	—	—	—	1	0·1
26–35	2	0·4	72	10·7	17	26·2	—	—	—	—	91	7·5
36–45	8	2·8	58	19·0	244	46·5	78	54·6	—	—	388	30·7
46–55	6	2·8	12	16·4	81	38·4	232	55·0	65	51·6	396	38·0
56+	4	3·1	5	12·8	17	37·8	50	39·4	162	47·6	238	35·0
	20	1·1	148	12·1	359	42·5	360	51·9	227	48·7	1,114	21·8

periods at the face there is a fall in the proportion of pneumoconiotics as they become older.

But in considering the time spent at the coal face, there appears to be a rise in the proportion of affected men with increasing face experience which, on the whole, tends to stabilize after 20 years. About 1% of the men with no face experience, 12% with one to 10 years' exposure, 42% with 11 to 20 years', 52% with 21 to 30 years', and finally 49% with over 31 years' exposure, had pneumoconiosis.

Pulmonary Tuberculosis.—In diagnosing pulmonary tuberculosis the suggestion made in the notes accompanying the P.R.U. set of standard films was in general followed: shadows which might be tuberculous were diagnosed as such in films with pneumoconiosis of less than Category 2, while in films with Category 2 or 3 pneumoconiosis in which any localized shadow suggested tuberculosis or early massive fibrosis, Category A was diagnosed unless the shadow was characteristic of healed inactive tuberculosis. Men with clinically significant pulmonary tuberculosis necessitating referral to chest clinics number three, five, and four respectively in collieries K, L, and M, but in colliery N 22 men were referred to chest clinics. This is approximately 3 per 1,000 in the first three pits taken together, and 11 per 1,000 in pit N.

The proportion of men with healed pulmonary tuberculosis (excluding primary complex) was also much higher in colliery N which had 12·7% compared with an average of 1·7% for the other three (Table 12).

TABLE 12
MEN SHOWING RADIOLOGICAL EVIDENCE OF HEALED PULMONARY TUBERCULOSIS (EXCEPT PRIMARY COMPLEX)

Age in Years	Colliery							
	K		L		M		N	
	No.	%	No.	%	No.	%	No.	%
16–25	1	0·3	1	0·6	3	1·6	3	1·3
26–35	7	1·7	—	—	1	0·4	22	5·4
36–45	2	0·6	1	0·5	10	3·3	53	12·4
46–55	7	2·4	1	0·8	11	4·0	63	18·3
56–65	3	1·6	2	1·6	15	8·5	63	32·5
	20	1·3	5	0·6	40	3·3	204	12·7
Standardized Rates		1·4		0·6		3·2		12·6

The percentage in collieries L, M, and N rises with age, being nearly doubled between 46 and 55 years and 56 and 65 years. The figures for P.M.F., assuming that it is essentially simple pneumoconiosis plus tuberculosis, do not reflect the difference between colliery N and the rest, and it is possible that this is the result of the greater disablement of men with P.M.F. and their withdrawal from pit work.

Non-attenders.—The results of the follow-up of non-attenders are shown in Table 13.

TABLE 13
MEN NOT RADIOGRAPHED BUT VISITED BY A SOCIAL WORKER

Colliery	Men Visited		Already Certified	Men not Interviewed Personally	Total
	Non-face-workers	Face-workers			
K	57	39	1	2	99
L	33	26	—	—	59
M	64	46	—	12	122
N	80	63	10*	172†	325
Total	234	174	11	186	605
% of total number of men on pay-roll at all collieries	4·1	3·0	0·2	3·3	10·6

* One with pulmonary tuberculosis
† 116 (68%) of these men were under 35 years of age; the majority were surface men.

The information from these visits was very important, in that it served to show what sort of worker had not been examined and how much the non-attendance was likely to influence the validity of the results. Many of the lapsed were young boys, men who had never been employed underground, or men who had worked most of their time away from the coal face in relatively dust-free conditions. A number of men were found to have been radiographed after all, and a few were known cases of pneumoconiosis who did not feel that the survey concerned them. One hundred and seventy-two men could not be traced at Pit N, mainly because they had no address at the colliery or had left their last address without notifying the colliery of the change. These were mainly surface men and were probably not regularly employed. Only a few men, all at Pit M, were willing to attend for radiology after the visit. Only 3% were not interviewed personally, but some information about them was obtained from relatives.

The number of non-attenders in each pit who had done facework at any time is not large. The highest number (63) was at Pit N, the largest pit, and the smallest number (26) at Pit L, the smallest pit and the most compact community. From these findings it is reasonable to assume that the men who were examined were practically the total of those exposed to dust, and that the results of the surveys are applicable to the pits as a whole.

The Environment.—A detailed account of the past working conditions in these pits was not obtainable directly, and no dust counts had been done, but it was known that ventilation had been a serious problem in Pit N in the past. The seams worked

and the type of coal produced in these pits are mixed, and include both the hard-texture coking coals as well as the softer gas and steam coals, but no conclusions could be drawn about differences in dustiness of the various seams which were worked. In Pits N and K bord and pillar work in blind headings was done until quite recently, but the tendency was to change to better ventilated, long-wall work. Pit L was worked by hand hewing until 1927, when pneumatic picks began to be introduced. Some wet cutting was in use in Pit N, but at the time of the survey there was no water infusion.

Mechanization was not introduced at any precise time, but was a gradual and patchy process which started at different times in the different collieries, and even at different times in various districts in the same colliery. It does not even take the same form. For example, in a single colliery one district may be working with unmechanized hand hewing, another may be gradually introducing mechanized pneumatic hewing, and yet another fully mechanized using coal cutters. The important thing is not whether the mine is mechanized but to how much mechanization a man has been exposed during his working life. An assessment of the degree of mechanization to which the men have been exposed is therefore best made from their occupational histories (Table 14).

TABLE 14
PROPORTION OF TIME SPENT IN VARIOUS TYPES OF FACEWORK AT EACH COLLIERY FROM OCCUPATIONAL HISTORIES

Type of Work	% Years Spent at It				
	Colliery				Total
	K	L	M	N	
Hand hewing	22	38	32	22	26
Pneumatic hewing	34	26	6	16	20
Hewing, unspecified	—	8	2	2	2
Coal cutting	4	2	8	6	6
Stonework	26	16	24	30	26
Filling	4	4	20	16	12
Deputy	10	6	8	8	8
	100	100	100	100	100

Twenty-two to 38% of the miners' time had been spent hand hewing. In Mine M only 6% of their time had been spent pneumatic hewing, but from 16 to 34% in the other three mines. Stonework in the rock above or below the coal seam used from 16 to 30% of their working life, and filling or shovelling coal either into "tubs" or trucks or on to a conveyor belt took from 4 to 20% of their time. On the whole, about a quarter of the working life up to when the men were radiographed was spent hand hewing and another quarter doing stonework. About one-fifth was spent pneumatic hewing and much smaller amounts of time doing other jobs.

Discussion

This survey suggests that there may be more simple pneumoconiosis in County Durham than was previously thought. Such evidence as there was from visits of a mass miniature unit to pits (McCallum, 1952) suggested a prevalence of from 3 to 6%, but the survey described here shows that the true prevalence, including all categories, is 32%, or 22% from Category 2 upwards for the whole pit population.

The pathology of pneumoconiosis of coal-miners appears to be identical in widely different coalfields (Heppleston, 1951), so that these results may be compared with those from other coalfields.

Figures previously published from the Pneumoconiosis Research Unit (Cochrane, 1951) for four pits in England gave prevalence rates for all categories of pneumoconiosis varying from 26·4% to 61·8%, but these referred only to "underground" workers. In the surveys reported here the figures refer to all the workers at the four collieries, including those above ground, but excluding coke workers. Many older men transfer to surface work from the coal face, so that the inclusion of screeners and timber yard men gives a more complete picture than would underground workers only, for chest radiography in pneumoconiosis measures a man's past, but not his present, exposure to dust.

The proportion of men who were radiographed in the (Welsh) Rhondda Fach Scheme (Cochrane, Cox, and Jarman, 1952) was 99% in four collieries, using a full-time staff and a special unit. In the Durham survey reported here, using a part-time staff and a standard Regional Board mass miniature unit as a mobile large film unit, 89% of the men in four collieries were radiographed.

In the Rhondda Fach survey about 13% of miners and ex-miners had progressive massive fibrosis. Our figure was 2%. This bears out an impression gained from the previous investigations in Durham that this type of disease may be more common in South Wales than in the North-East.

It is clear that these Durham collieries have been dusty enough in the past to produce pneumoconiosis, and that if the conditions remain unchanged they will continue to do so in the future. The men with well marked lung changes (Category 2 upwards) have spent a higher proportion of their working lives in these mines than those with normal lungs or with Category 1 changes. Unfortunately, no measurements of dust concentration over the years

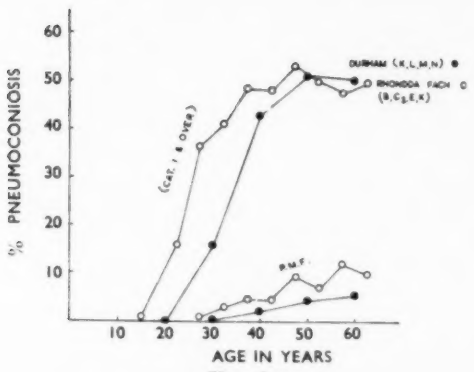

FIG. 3

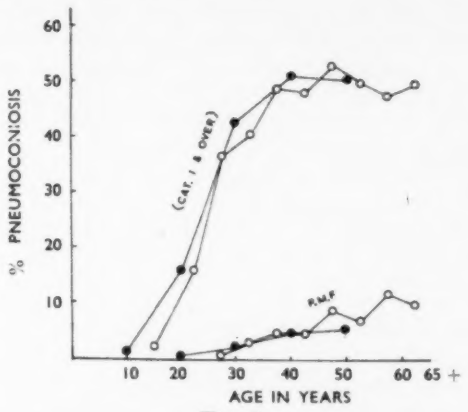

FIG. 4

FIG. 3.—Percentage of pneumoconiosis (Category 1 and over) in four Durham collieries, and four in the Rhondda Fach by years of age. Simple pneumoconiosis and P.M.F. are shown separately. The Rhondda Fach figures refer to all underground workers, the Durham figures to all men who have done more than six months' work at the coal face.

FIG. 4.—The graph for Durham collieries (Fig. 3) has been moved 10 years to the left to show the very close similarity between the two areas.

preceding these surveys exist which can be used to match the radiological results.

In County Durham, men between the ages of 14 and 20 years have usually worked at relatively dust-free jobs on the surface or underground away from the face. In only a few instances have men under 20 years of age already done facework for two or three years. After the age of 20 it is usual for the men to progress through jobs which take them to the face intermittently, such as driving and putting, to actual facework as hewers, cutters, stonemen, etc., if they remain in pit work. It is at this point that heavy exposure to dust probably begins, with the resulting rise in prevalence of pneumoconiosis after the age of 35 years, or after about 10 years at face-work.

Cochrane and Gilson (personal communication) compared our results from this survey of four Durham pits with data from four pits in the Rhondda Fach, South Wales. The South Wales figures refer to " all miners working underground " while those from Durham refer to all men with a history of six months or more at facework, that is, men actually hewing or cutting the coal, doing stonework, shifting conveyors, or whose work takes them constantly to and from the face such as putting and driving. When the proportion of men with pneumoconiosis of Category 1 or more is analysed by age (Fig. 3), the similarity between the two groups is very striking when all the variables in radiographic technique, film viewing, and in taking occupational histories are considered. Furthermore, there is a fairly regular eight to 10 years' difference between the two groups, and if the Durham figures are moved 10 years to the left (Fig. 4) there is a remarkable agreement between both simple and complicated pneumoconiosis in the two areas. Cochrane and Gilson point out that on the average the Durham miners went on to the coal face at the age of 20 to 25 years, which is approximately eight to 10 years later than is usual in South Wales. They think that the difference in prevalence of progressive massive fibrosis between the Rhondda Fach and the Durham pits may be due to this difference in age at which heavy dust exposure began in the two areas. As P.M.F. begins on a basis of Category 2 or 3 pneumoconiosis (Cochrane, Fletcher, Gilson, and Hugh-Jones, 1951), the Durham miners of the same age as the Welsh miners had less time in which to develop P.M.F. Cochrane and Gilson conclude that coal-face dusts in Durham have on the average in the last 40 years had the same power of producing simple pneumoconiosis as those in the Rhondda Fach.

The tendency for the number of men in each category of pneumoconiosis to become stable at a certain level may be due to progression from the category below being roughly balanced by withdrawals in the more advanced categories (3, and P.M.F.) in which disability from the pneumoconiosis may be more marked. Variations in dustiness in the past, of which there is no record, or a tendency for some older men to transfer to deputy work which takes them intermittently to the face may have a similar result. It is possible also that in some men who have reached one of the simple or complicated categories of 2 or more further accumulation of dust may not be detectable radiologically and the condition may appear to be stationary. The method of assessing the disease radiologically is still

only relatively accurate and there are many variables. Furthermore, the presence of focal emphysema may explain some of the discrepancies in individual cases by masking the dust foci and giving the appearance of a lower category and this may tend to happen more as the men become older and more emphysematous.

Even after 30 years at the coal face more than a third (34·8%) of the radiographs were normal, which does not make it easy to accept wholly a simple time and dust concentration hypothesis for the radiological appearances, although this may explain the regularly increasing categories in the first 20 years of exposure to dust at the coal face.

The proportion of men who withdraw from their well paid coal-face work increases with age, but not with the radiological category of simple pneumoconiosis. This may well be an important point, because in this condition (as in many others) it is only too easy to be overimpressed by the radiograph. But when the appearance is that of progressive massive fibrosis the men tend to give up facework sometimes perhaps because they do not feel well enough, but it must often be because they are advised to do so. Withdrawal from facework is, perhaps, a rough and ready measure of disability, but it is one which is real, not only to the man because it means having to step down in his job with the resulting financial hardship, but also to the industry, because it means a loss of people at the point of production through a preventable industrial disease. A refined physiological test will detect changes in pulmonary function early, but to give industrial information it still has to be linked to a man's ability to work at his ordinary job.

Radiological pneumoconiosis on the scale seen here is important because of its medico-legal implications, for if Category 2 or more is taken as the lowest radiological degree likely to be recognized by a pneumoconiosis medical panel of the Ministry of National Insurance, about 39% of the faceworkers at these pits would have grounds for an application to such a panel. If men are to receive compensation for 1% "disability" or "loss of faculty", and if this is regarded as equivalent to radiological pneumoconiosis which is just diagnosable, a greater proportion even than this will have such grounds. Probably only a few of these men have definite symptoms, but the industry could be faced with a serious situation in which a high proportion of key workers were required either to work under approved conditions which might not exist to a sufficient extent, or to change to non-coal-getting work elsewhere in the colliery. This situation is not desirable either from the men's or from the industry's point of view, nor is it necessary. In most cases the men should be allowed to continue at their own work if they are physically capable of doing it, but they should be under medical supervision. The man's own wishes should, of course, also be consulted and the position must be explained to him ; at the same time, if he can be assured that measures to suppress dust are being actively pursued, his anxiety about the dust which he is breathing may to some extent be allayed and his cooperation ensured in suppressing it. Men with progressive massive fibrosis should be allowed to continue at their job if an adequate series of sputum tests, including culture, show that they are free from tubercle bacilli, and close medical supervision is continued, since progression of the lesions in these men probably occurs irrespective of whether they remain in the mine atmosphere or not (Davies and others, 1949).

The fact that half of the faceworkers of middle age show definite radiological signs is of importance, not only because of the potential disability of some of them, but also from the economic and psychological aspects. Practically all these men were regularly at work at the time of the survey and had no disability or were insufficiently disabled to arouse suspicions of occupational disease. Disability in the sense that a change to lighter work had occurred was evident either among the elderly or among those with progressive massive fibrosis. However, it is not easy to distinguish their symptoms from those due to advancing age or bronchitis with emphysema. It may well be that these are the two important variables and that too much attention has been paid in the past to the radiological appearances. If a man who has done facework in this coalfield for 20 years or more has his chest radiographed for any reason, there is more than a 50% chance that some dust opacities will be found, and this is in accordance with clinical out-patient experience of coalminers in the Newcastle area. This has obviously an important bearing on the diagnosis of chest disease in faceworkers, for the finding may be very misleading if its frequency is underestimated, and in the management of men in whom pneumoconiosis is found incidentally either by mass radiography or hospital investigation for any cause. If breathlessness is the main complaint, other causes such as unrelated lung or heart disease or systemic disease elsewhere must first be excluded, particularly if the disability is out of proportion to the amount of pneumoconiosis.

These results demonstrate how little certification figures may relate to the actual amount of radiological abnormality. Colliery N, which has by far

the worst record judged by the certification figures, is seen to be only a little worse, in fact, than the others. Many of the men lived in neighbouring urban areas with probably greater risks of tuberculous infection, and it is possible that this is reflected in the high certification figures. Colliery L, on the other hand, is seen to be much worse than certification figures suggest.

With such a high percentage of men showing radiological signs of the disease in the Durham coalfield, policy, treatment, and advice to men who are found to have such changes must be very carefully considered. The disease presents not only as a medical but as an economic problem for which legislation acting through medical boards provides only a partial and, indeed, a rather inflexible solution. It is not always appreciated that the effect of informing a hitherto healthy man that he has " pneumoconiosis " is often harmful. Some other more tactful term which will convey to him that his condition will not necessarily deteriorate is required. Similarly, a man should not be removed from his own job without careful consideration, provided he is physically capable of doing it (McCallum, 1953). But at the same time it must be remembered that pneumoconiosis has medico-legal implications, and that the pneumoconiosis medical panels who see the patients can only operate within their statutory framework.

It is clear that in the recent past faceworkers in the Durham coalfield have been exposed to excessive dustiness in their work and that radiological pneumoconiosis is, as a result, widespread amongst them. Why a substantial proportion of men in these pits remained practically free from radiological abnormality is a question which still requires an answer.

Summary

Surveys in four Durham coal-mines, where 89% of the men were radiographed, show that 32% of them have some evidence of coal-miner's pneumoconiosis and 22% have radiological Category 2 or more. Only 2% have progressive massive fibrosis and most of these are early stages.

Films were taken of 5,118 men, and all four collieries showed similar prevalence figures, although they were geographically spread over the coalfield.

Withdrawal from the coal face of men with pneumoconiosis in County Durham is associated with advancing age and particularly with progressive massive fibrosis.

Radiological pneumoconiosis increases in prevalence both with rising age and with length of time spent at facework. Between 26 and 35 years of age nearly 8% of men have pneumoconiosis of Category 2 or more, while between 36 and 45 years of age the proportion of men affected rises sharply to 31%. Similarly, after one to 10 years at facework 12% of men have Category 2 of pneumoconiosis or more, but after 11 to 20 years at the face the proportion rises to 42%.

Length of time at facework is a more important factor in producing the radiological signs of pneumoconiosis than is the length of time spent in the pit as a whole. The critical period at which the effect of facework becomes demonstrable is at about 35 years of age or after about 10 years at facework.

There is a remarkable similarity between the proportion of men at different ages with pneumoconiosis in Durham and South Wales, allowing for a difference in the age at which heavy dust exposure begins.

From the point of view of both the men and the industry as a whole it is better to allow men with pneumoconiosis to continue at their facework under medical supervision, if they are willing to do so, and to persevere with measures to make the work less dusty and so reduce the risk of progression of simple pneumoconiosis or of fresh cases developing.

In County Durham neither past certification figures nor previous estimates from mass miniature surveys show a close relation to the true prevalence as reported here.

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THE ENERGY EXPENDED WHILE WALKING IN STOOPING POSTURES

BY

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In mine roadways the roof is frequently so low that it is impossible to walk in the natural erect manner and it is necessary to stoop, sometimes to a considerable extent. Indeed, in a very low place it may be necessary to travel some distance on all fours. Walking in low roadways can be very fatiguing when a pronounced stoop is necessary, for the energy cost of walking in such a posture is greater than that incurred in walking in the usual erect posture at the same speed.

In a study of the energy output of coal-miners during work Moss (1935) made observations of the oxygen intake during walking in different postures along a level floor at a constant speed of 3½ miles per hour. His subjects were eight miners, all trained rescue men, who were accustomed to wearing a mouthpiece and nose-clip and were also used to low roadways. Experiments were made with the subjects walking in four postures : (*a*) erect ; (*b*) in a posture referred to as "half stoop", in which the subject stooped enough to reduce his height by about 20% ; (*c*) " full stoop ", in which the height was reduced by 40% ; and (*d*) " all fours ", in which the subject walked on hands and feet and reduced his height by about 50%.

Moss concluded that the energy cost of walking at 3½ miles per hour in the half-stoop posture was about 20%, in the full-stoop posture 66%, and on all fours about 73% more than the cost of walking erect, and he remarked that the wastage of energy due to walking along low roadways must make an appreciable difference to a man's output of work at the coal face.

From the brief mention of the experimental technique given in Moss's paper it appeared that the energy cost with the greater reductions of height was underestimated. Three expiratory air samples of three-, two- or one-minute duration, according to the exacting nature of the work, were taken and averaged, and the average values of oxygen intake thus determined were taken as representing the energy output when walking in the various postures. No allowance appears to have been made for the large oxygen debt which is incurred during a short bout of such violent exercise as progressing on all fours at 3½ miles an hour.

Moss's results appeared to be of some practical significance, and soon after they were published we made a series of observations on ourselves in which we walked at various speeds and as nearly as possible in the postures described. In view of the attention now being devoted to the physiological problems of mining, it may be of some interest to report the results of those observations.

Method of Experiment

The experiments were carried out on the smooth wooden floor of a long corridor. Ordinary walking was done at rates of 2 to 5 miles an hour, half-stoop walking at 2 to 4 miles an hour, and in the full-stoop and all-fours postures the speeds ranged from 2 to 3½ miles an hour.

For the measurement of respiratory exchange the usual Douglas-Haldane technique was employed.

Preliminary experiments showed that in the erect and half-stoop postures a steady state was readily attained, and the results for these postures presented here were obtained under steady-state conditions. Owing to the severe nature of the exercise it was found impossible to continue full-stoop walking for more than a minute or a minute and a half, or walking on all fours for more than 40 to 50 seconds, so that in estimating the energy expenditure while walking in these postures the oxygen consumption during recovery had to be ascertained and allowance made for the heavy oxygen debt. With these very short spells of exercise the estimates of total oxygen usage may be subject to some error, but they do at any rate show the order of magnitude of the oxygen consumption.

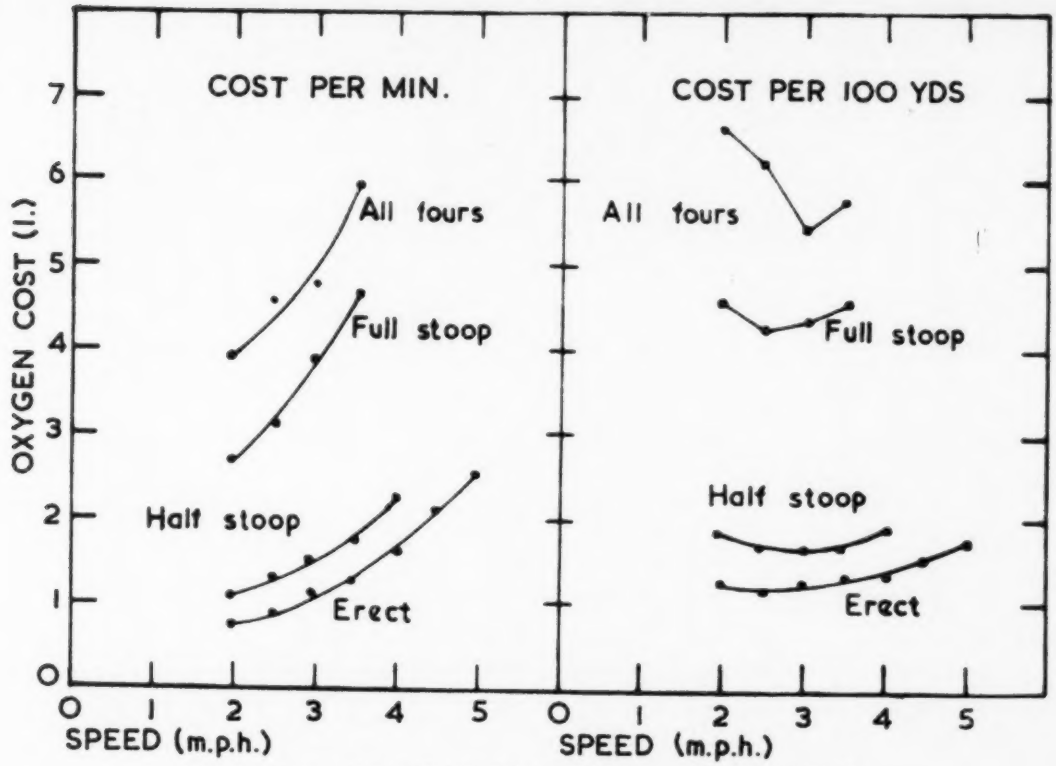

FIG. 1.—Oxygen used by subject I walking in different postures at different speeds.

The walking at various speeds was done by Subject I (aged 41 years, height 68 in., weight 144 lb.), and further experiments at 3½ miles an hour were done by Subject II (aged 33 years, height 65 in., weight 142 lb.). Neither subject was in athletic training, but a few years previously both had had much experience in traversing low mine roadways.

Experimental Results

The oxygen used by Subject I while walking at different speeds and in different postures is shown in Fig. 1, and the cost of walking in the various postures relative to that of walking erect at the same speed is shown in Table I. At any given speed the cost of walking with a stoop was distinctly greater than that of walking erect. With a height reduction of 20% (half stoop) the cost was 31 to 49% greater; with a reduction of 40% (full stoop) the cost was about three and a half times that of walking erect; while the cost of progression on all fours was four or five times that of normal walking. At 3½ miles an hour on all fours the oxygen cost was in the neighbourhood of 6 litres a minute.

TABLE I
OXYGEN REQUIREMENT OF SUBJECT I WHEN WALKING WITH A STOOP AND ON ALL FOURS

Speed (miles per hour)	Oxygen Requirement for Normal Walking (l. per min.)	Oxygen Requirement (as percentage of that of normal walking) when Walking		
		With Half Stoop	With Full Stoop	On All Fours
2	0·74	149	364	526
2½	0·88	143	356	520
3	1·12	132	345	427
3½	1·34	131	349	442
4	1·63	138	—	—

Experiments in which Subject II walked at 3½ miles an hour, the speed used by Moss, gave similar results. Fig. 2 shows that the oxygen costs of the two subjects were almost identical.

Walking in the full-stoop posture or on all fours, especially at 3½ miles an hour, was very strenuous, and although the exertion could be continued by us for only about one minute an oxygen debt of up to 3½ litres was incurred. This is illustrated by the results of an experiment in which Subject II walked in the full-stoop posture for one minute after previously reclining in an armchair.

In this experiment the oxygen requirement of walking for one minute was 5·2 litres, of which 1·73

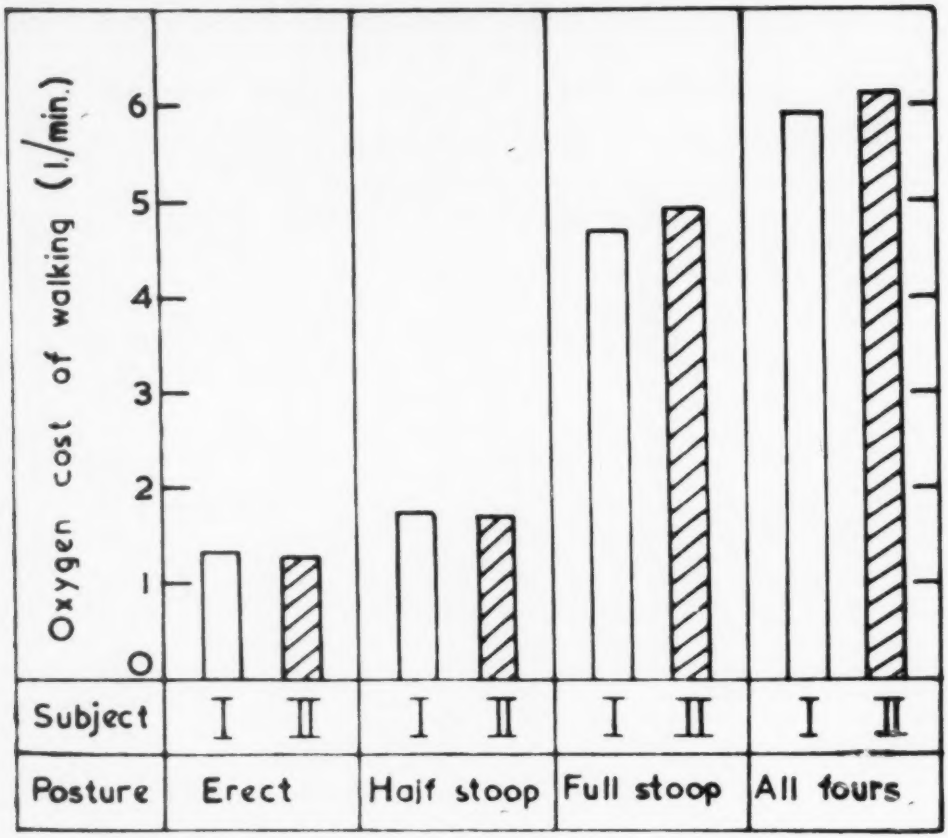

FIG. 2.—Comparison of oxygen consumption of both subjects under similar conditions.

litres was the amount absorbed during the one minute of exercise while the remainder, 3·47 litres, was the oxygen debt incurred, *i.e.*, the excess of the oxygen intake during the period of recovery over the intake during rest (thus, $3 \times 1{\cdot}012 + 7 \times 0{\cdot}429 + 5 \times 0{\cdot}359 - 15 \times 0{\cdot}291 = 3{\cdot}469$ l.). Over the short period of work the pulmonary ventilation rate was raised to nearly five and a half times the previous resting value, and it averaged five times that value during the first three minutes of recovery.

The last column of Table 2 shows that during the first 10 minutes immediately after walking there was considerable hyperventilation, for the ratio of the rate of lung ventilation to the rate of oxygen intake was roughly from 50 to 60% above the ratio in the period of rest before work, and the respiratory quotient was 1·14. In the light of conclusions reached by us during an earlier study of static effort (Bedford, Vernon, and Warner, 1933) we were much interested in this hyperventilation and for walking in the various postures and at the various speeds we have calculated ventilation/oxygen-intake ratios. For the experiments in which the subject was not in a steady state while walking we have, in calculating these ratios, used the total oxygen cost of the work and a figure which we have taken to represent the total ventilation during work. It has been assumed that during the recovery period the volume of ventilation in excess of that corresponding to the ventilation rate during the pre-work period of rest was the "ventilation debt" due to exercise, and that has been added to the ventilation during exercise to obtain a figure representing the

TABLE 2
SUBJECT II WALKING AT 3½ MILES AN HOUR WITH FULL STOOP

Activity	Rate of Oxygen Intake (l./min.)	Ventilation Rate (l./min.)	Ventilation /O_2 Intake
Reclining in armchair after previous rest of 15 min.	0·291	5·39	18·5
Walking, full stoop, 1 min.	1·728	29·30	17·0
Recovery after work, first 3 min. ..	1·012	27·79	27·5
" " " next 7 min. ..	0·429	12·47	29·1
" " " next 5 min. ..	0·359	7·10	19·8

TABLE 3

VENTILATION RATES AND VENTILATION/OXYGEN-INTAKE RATIOS DUE TO WALKING IN VARIOUS POSTURES AT DIFFERENT SPEEDS

	Subject I							Subject II
	Speed (miles per hour)							
	2	2½	3	3½	4	4½	5	3½
Walking erect								
Ventilation rate (steady state) in l./min. ..	14·1	16·0	19·3	23·1	30·8	39·1	54·0	21·9
Ventilation (l.) per 1·0$_2$	19·1	18·1	17·3	17·5	18·9	18·9	21·0	17·7
Walking with half stoop								
Ventilation rate (steady state) in l./min. ..	20·4	22·8	28·0	34·4	45·8	—	—	30·7
Ventilation (l.) per 1·0$_2$	18·5	18·0	18·9	19·6	20·3	—	—	18·2
Walking with full stoop								
Ventilation rate during work (l./min.) ..	28·1	29·0	26·7	27·2	—	—	—	28·3
Ventilation per 1·0$_2$ intake during work (l.)	20·7	21·9	21·1	20·3	—	—	—	17·5
Total ventilation requirement of work (l./min. of work)..	72·0	91·0	120·7	133·6	—	—	—	144·5
Ventilation requirement ÷ oxygen cost of work	26·8	29·0	31·3	28·6	—	—	—	29·3
R.Q. in first 3 min. of recovery	—	—	1·16	1·23	—	—	—	1·25
Walking on all fours								
Ventilation rate during work (l./min.) ..	32·4	38·0	34·8	38·2	—	—	—	27·3
Ventilation per 1·0$_2$ intake during work (l.)	27·4	26·3	29·9	29·8	—	—	—	21·7
Total ventilation requirement of work (l./min. of work)	118·7	164·9	204·9	208·4	—	—	—	195·3
Ventilation requirement ÷ oxygen cost of work	30·5	36·0	42·9	35·2	—	—	—	31·9
R.Q. in first 3 min. of recovery	1·05	1·24	1·25	1·30	—	—	—	1·29

ventilation due to work. For the experiment reported in Table 2 that figure is 154·6 litres, and when it is divided by the oxygen cost of the work, 5·2 litres, the ratio of the ventilation requirement to the oxygen cost of the work is found to be 29·7.

The average ventilation rates and ventilation/oxygen-intake ratios for both subjects are shown in Table 3, and for those experiments in the two more strenuous postures in which separate collections of expired air were made for the first three minutes of recovery the respiratory quotients during that period are also shown.

During erect and half-stoop walking at all speeds the ventilation/oxygen-intake ratios for Subject I were all below his average resting value of 22, and the lowest values occurred at the more comfortable speeds. In the full-stoop posture, where the chest was constricted, the ventilation rate during work did not increase at the higher speeds, and the ventilation/oxygen-intake ratio, though higher than in the easier postures, remained below the average resting value. In this posture there was much hyperventilation after the exertion, as is shown by the higher ventilation/oxygen-intake ratios based on the total ventilation and oxygen requirements of the work and by the high respiratory quotients where these are available. With walking on all fours higher ventilation rates were achieved during the very short periods of work, but this exhausting effort caused yet more hyperventilation after work than occurred after walking with a full stoop. The experiments on Subject II gave results very similar to the comparable figures for Subject I.

Our rates of oxygen intake while actually walking on all fours were only about two-thirds of the average rate for Moss's miners, but much of this difference is probably attributable to differences in experimental procedure. We started that severe exercise immediately after resting for some 25 minutes, but if, as seems certain, Moss did not consider oxygen debt, it is unlikely that his subjects were rested before each determination of oxygen intake. It would then follow that in experiments lasting only one or two minutes their oxygen intake

TABLE 4

RATES OF OXYGEN INTAKE OF SUBJECT II WALKING AT 3½ MILES AN HOUR COMPARED WITH RATES REPORTED BY MOSS

Time	Subject II		0_2 Intake (l./min. of Six of Moss's Miners in Similar Posture	
	Activity	0_2 Intake (l./min.)	Mean	Range
12.30–	Fore-period: walking erect for 1 min.	—	—	—
12.31–	Walking erect, 4 min. ..	1·32	1·12	0·96–1·27
12.35–	Standing, 2 min.	—	—	—
12.37–	Walking, half stoop, 3 min.	1·67	1·33	1·17–1·56
12.40–	Standing, 2 min.	—	—	—
12.42–	Walking, full stoop, 1 min.	1·76	1·92	1·54–2·35
12.43–	Standing, 3 min.	—	—	—
12.46–	Walking, all fours, 42 sec...	1·99	1·94	1·59–2·36

would tend to be higher than if they had started exercise immediately after a long rest.

One experiment was done in which Subject II walked in each of the four postures in turn at 3½ miles an hour, with intervals of only two or three minutes between spells of walking. Table 4 shows the rates of oxygen intake, and for comparison the average and the maximum and minimum values reported by Moss for the six miners who completed experiments in all postures are also shown. The two miners who failed to complete the experiments in the most strenuous posture had oxygen intakes in the easier postures which were substantially higher than the maxima shown in Table 4.

In each posture Subject II's rate of oxygen intake during exercise lay within the range found by Moss in his miners, although in the erect and half-stoop postures his intakes were slightly in excess of those shown in Table 4, and in the most severe posture it differed by less than 3% from Moss's average.

Discussion

The results which have been described show clearly the desirability of maintaining adequate headroom in mine roadways. Walking with a stoop, even when the body height is reduced by only 20%, raises the energy cost of walking by between 30 and 50%, and as the extent of stooping increases the cost rises rapidly. The cost of progression in what is described as the " full-stoop " posture, *i.e.*, with a height reduction of 40%, is three and a half times that of normal walking, and while it may be unusual to stoop quite so much for long distances, one frequently has to walk a considerable way stooping to an extent which probably doubles the cost of walking at a given speed. If it happens that considerable distances must be traversed while stooping in a deep and hot seam, the additional heat stress imposed by the posture may be a serious handicap.

Even at the coal face there is need for such headroom as can be given. Kommerell (1929), in a study of shovelling while in a stooping position, found that a reduction of the height from floor to ceiling from 1·2 to 1 metre caused a rise of 10% in the oxygen cost of shovelling at a given rate.

In the experiments here described we reproduced as nearly as possible the postures adopted by Moss's miners. We could have continued walking in the half-stoop posture for considerable periods without difficulty, apart from the discomfort and increasing fatigue due to postural strain, but with the full stoop we could not long continue without resting.

It is well known that during the early stages of recovery from severe exercise there is an elimination f carbon dioxide and a high respiratory quotient, and the high respiratory quotients and high ventilation/oxygen-intake ratios, apart from the high oxygen costs, that we have noted show the severity of walking with a full stoop or on all fours. These modes of progression entail considerable postural strain, and it seems possible that the high ventilation/oxygen-intake ratios may be due to some extent to the discomfort arising from such strain. Bedford, Vernon, and Warner have earlier (1933) shown that whereas the ratio of ventilation to oxygen intake falls below the resting value during dynamic work, it increases considerably above the resting value when any static effort is sufficiently prolonged. The rise in the ratio, it was found, ran parallel with the feelings of strain associated with such effort. Pain caused such a rise in the ratio ; thus, when a painful faradaic stimulus was applied to the legs of a subject who lay resting in a reclining chair, the ventilation/oxygen-intake ratio was raised as high as 52·6 with a respiratory quotient of 1·37, even though the rate of oxygen intake was only 0·49 litre per minute. The rise in the ventilation/oxygen-intake ratio which occurs in static effort was ascribed by us to the influence of painful sensations of strain.

When Moss published the results of his experiments he remarked that they showed clearly the wastage of energy that occurs when miners have to walk along low roadways, and commented that such wastage must make an appreciable difference to a man's output of work at the coal face, especially if the air temperature is high. The experiments described here show the extra cost of walking with a stoop to be much greater than Moss had found, and they therefore give added point to his comments. Walking for appreciable distances in low roadways is indeed likely to be inimical to working efficiency.

It may be possible to compute whether or not it would be economic to accept some reduction in efficiency instead of incurring costs in increasing the height of roadways, but the result of such computations cannot necessarily give the whole answer to the problem.

Discussing the responsibilities of management in industrial hygiene recently, one of us (Bedford, 1954) remarked that " methods of work, machines, and the working environment should be such as not to impose undue strain. The intelligent application of the results of physiological research can do much to ease the load on the worker and to improve his efficiency ". Mining is arduous work and walking in roadways that are unnecessarily low causes undue strain, and it is therefore gratifying to note that statutory provision is now made for the improvement of mine roadways. Section 35 of the Mines and Quarries Act, 1954, requires that with certain

exceptions every length of a road in a mine which is made after the implementation of the Act and which is used at the beginning or end of a shift by not less than 10 persons for the purpose of walking to or from their working places in the mine shall be not less than 5 ft. 6 in. high throughout. If an inspector of mines considers that any such road made before the passing of the Act should not be used unless it is heightened, he may require that it shall be increased to a height not exceeding 5 ft. 6 in. which he will specify.

The energetic application of these provisions should result in great improvements which are long overdue.

Summary

Experiments on two subjects are reported in which the energy cost of walking—erect, stooping, and on all fours—was measured. At a given speed, when walking with a stoop sufficient to reduce a man's height by 20%, the energy cost was from 30 to 50% above that of normal walking, while walking with a stoop causing a height reduction of 40% cost three and a half times, and walking on all fours four and a quarter to five and a quarter times as much energy as normal walking.

We are indebted to Dr. R. K. Macpherson for valuable criticism.

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TOLERANCE OF MEN TO WORK IN HOT, SATURATED ENVIRONMENTS WITH REFERENCE TO MINES RESCUE OPERATIONS

BY

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A number of authors, for example, Fleisher, Stacey, Houghten, and Ferderber (1939), Robinson, Turrell, and Gerking (1945), Eichna, Ashe, Bean, and Shelley (1945), McArdle, Dunham, Holling, Ladell, Scott, Thomson, and Weiner (1947), and Ellis, Ferres, Lind, and Newling (1953), have provided information on upper tolerable limits of warmth for men. A recent review by Weiner and Lind (1954) showed that there is a fairly good measure of agreement between the results of these workers. Most of this experimentation was conducted on men resting or doing relatively light work for exposures of from two to eight hours, and often did not involve a large or rapid rise of body temperature.

In the mining industry, the part-time rescue personnel who undertake the various types of rescue operations are required to work in actual practice for periods of not more than two hours in adverse thermal conditions. Body temperatures in such circumstances would rise rapidly and it is during such a period of rapid physiological change that even trained men are very liable to experience severe distress and incapacitation, though there may be some improvement if body thermal equilibrium is attained (Eichna and others, 1945). For rescue purposes it is necessary to know the maximum period of endurance in hot environments which rescue teams can display without serious loss of efficiency. Present information derived from laboratory studies (such as those already mentioned) is almost entirely concerned with the environmental conditions in which a given task of fixed duration can be performed; moreover in these tasks (marching or step-climbing), which are not as exacting or complicated as the operations of rescue work, the criterion of tolerance usually adopted is the ability of the subject to re-establish thermal equilibrium. It is clear from Mackworth's (1950) and Pepler's (1954) findings that psychomotor disturbance will be in evidence at temperatures well below those at which thermal equilibrium is physiologically still possible.

The valuable paper by Roantree (1951) on the relation between wet-bulb temperature and length of time worked by fire-fighting teams in the Kolar Gold Field in India relates to men who are highly acclimatized to heat and his results could therefore not be expected to provide the information which could be safely used in this country. The data provided by Craig, Garren, Frankel, and Blevins (reported while this paper was being prepared in 1954), though concerned with tolerance times, are likewise not immediately applicable, as the subjects were deliberately acclimatized to work in hot environments and were wearing protective clothing of various kinds.

The types of operation to which rescue personnel in the mining industry in this country are called may be classified roughly into four categories in their order of frequency :—

(1) **Fire** (*a*) "Open"—starts with free flames, as from a spark. (*b*) "Gob"—starts by spontaneous combustion—heating within a coal seam. Dry-bulb temperature is usually high. Wet-bulb temperature may be quite low but rises according to the amount of free water from strata and the water used in fire-fighting. Air movement is often maintained at quite a high rate.

(2) **Explosion** (*a*) with fire; (*b*) without fire: Dry-bulb temperature usually high. Wet-bulb temperature usually low but with fire rises as in preceding category. Air movement often poor or absent.

(3) **Life Saving from Areas of "Black Damp" or "Fire Damp".** Dry-bulb temperature usually low or moderate. Wet-bulb temperature may be low or high. Air movement poor or absent.

(4) **Recovery of Sealed Areas.** Conditions are very variable. Dry-bulb temperature often moderate to high. Wet-bulb temperature often high. Air movement may or may not be present.

From the available data of past operations it appears that there is a considerable range in the thermal environments, both between and within

each of these categories. Conditions are often very severe. The most frequently recorded conditions fall into the range of dry-bulb temperature 30 to 45° C. (86 to 113° F.) and of wet-bulb temperature 24 to 35° C. (75 to 95° F.). The extremes of temperature in the records are dry-bulb temperature 23 to 71° C. (73 to 160° F.) and wet-bulb temperature 17 to 44° C. (63 to 111° F.). Air movement is variable, and often tends to make any given environment more severe; thus, when dry-bulb temperatures are high, as in a fire, air movement is frequently maintained in order to reduce fumes and the possibilities of explosion; where the dry-bulb temperature is low, air movement is often poor or absent. Men may have to work extremely hard in such conditions while wearing heavy rescue apparatus, and heat collapses have occurred.

Following a request from the National Coal Board, a series of experiments was undertaken, using 36 volunteers, each of whom was exposed three times to varying saturated temperatures.

The aims of these experiments were (*a*) to provide an estimate of "tolerance time" of men engaged on a stipulated routine in various hot, saturated environments; (*b*) to determine whether there is a demonstrable difference in the reactions to such conditions (i) in relation to age, and in particular whether the present upper age limit of 45 years for mines rescue personnel is acceptable or not, (ii) in relation to the different types of occupation in the mines rescue personnel, (iii) in relation to the two different types of self-contained breathing apparatus used in rescue work.

Experimental

Subjects.—The subjects were 36 mines rescue personnel chosen from a large group who volunteered for these tests. These men comprised 18 pairs, the members of each pair being of approximately similar physique as judged by height and weight; one member was drawn from a younger (19–31 years) and the other from an older age group (39–45 years). The 18 pairs came from six different rescue stations, three stations from a division using self-breathing rescue apparatus employing compressed oxygen (apparatus 1) and three from a division using a liquid air apparatus (apparatus 2). There were thus three pairs of men from each rescue station, and these represented three occupational categories: "severe" (S) comprising men who normally work at the coal face; "mixed" (M) comprising fitters, electricians, etc., many of whom spend only part of the time underground; and "deputies" (D) who supervise work underground. For the purpose of the experiment the 36 men were tested as three teams of 12 men, each team being of similar composition with regard to age, occupation, and type of apparatus. Members of the mines rescue service are medically examined twice a year as a normal routine; the 36 volunteers were all re-examined and pronounced medically fit before being submitted to the present experimentation. Efforts are also made in the mines rescue service to maintain a good standard of physical training.

Clothing.—The subjects wore shorts, vest, socks, and boots, self-contained breathing apparatus, mining helmet, and safety lamp.

Work Routine.—The experimental task was designed to simulate a rescue operation, and comprised consecutively: (1) half an hour of walking at 2 m.p.h. wearing the self-breathing rescue apparatus (weight 40 lb.) and carrying a sandbag (weight 50 lb.) in cycles of four minutes followed by one minute rest on a stool; (2) a five-minute rest period sitting on a stool; (3) half an hour building a sandbag "stopping" using 24 sandbags of 50 lb each, carrying each bag singly for 15 ft. to build the stopping, in cycles of four minutes sandbagging, one minute rest. The energy cost of the three stages of this 65-minute routine was an average of (1) 170 kcal./m².hr., (2) 55 kcal./m².hr., (3) 250 kcal./m².hr., and the mean energy cost for the complete 65-minute task was 200 kcal./m².hr.

Thermal Environments.—Saturated environments were used in the present investigations since in mining rescue operations the moisture conditions are often near saturation as a result of natural water in the strata and that used in fire-fighting. Each team was exposed three times to various environments as follows (temperatures being shown in °C.). In order to minimize acclimatization effects, individuals made their successive visits at four-weekly intervals.

Exposure	Team I	Team II	Team III
1	29·4	30·8	29·4
2	29·4	30·8	33·6
3	32·2	35·0	37·8

Room temperatures were controlled to ± 0·5° C. of the target temperatures. The air speed in the chamber in all these experiments was less than 20 ft./min.; but because of the rate of walking required for the task, the effective air speed was between 150 and 175 ft./min.

Measurements.—Measurements were made of rectal temperatures by means of an indwelling rectal thermocouple inserted 10 cm. (see appendix), pulse rates counted by palpation over 30 seconds, sweat losses by nude weight losses, blood pressures by sphygmomanometer and stethoscope, metabolic costs of work and rest using Douglas bags, and the inspired-air temperature within the breathing apparatus by means of a 30 s.w.g. thermocouple.

Experimental Timetable.—The subjects rested, sitting, for 60 minutes before entry to the hot chamber. Beginning 35 minutes before entry, rectal temperatures and pulse rates were recorded at five-minute intervals until 30 minutes after removal from the chamber. Blood pressure was taken before the entry into the hot chamber, during the five-minute rest, and immediately before leaving the chamber. Nude weights were recorded five minutes before entering and five minutes after leaving

the chamber. The breathing apparatus was put on immediately before entry to, and taken off immediately after removal from, the chamber. Inspired air temperatures were taken every five minutes throughout the experiment.

Experimental End-point.—The aim of the investigation made it undesirable for the subjects to reach a state of collapse. Unless they elected voluntarily to leave the chamber, the subjects were removed when their rectal temperatures reached 38·8° C. (101·8° F.). The results of experiments by Ellis and others (1953) indicate that in saturated environments subjects with temperatures rising to this level are under obvious stress and may be approaching a point of incipient collapse, but would be able to leave the chamber in a reasonably fit condition, as is desirable in actual rescue operations. The validity of this criterion was well borne out in the tests as reported below.

In practice, especially at the higher environmental temperatures investigated, it was not always possible to achieve this end-point accurately since by the nature of the test the rectal temperatures rose quickly near the end of the exposure. In the less severe environments some men completed the 65-minute test without achieving a rectal temperature of 38·8° C. It has been necessary in some cases to make an interpolation or extrapolation of rectal temperatures to estimate the survival times. One man only of the 36 had a " low-threshold " rectal temperature of heat tolerance and in this case the tolerance time was based on his lower threshold (about 38·5° C.) and on the observer's assessment.

The 36 volunteers showed great interest and consistent enthusiasm throughout the investigation and this spirit was encouraged by the observers as much as possible, since motivation is without doubt at a high level in actual rescue emergencies.

Results

Analysis of the results in relation to the factors of age, occupation, and types of apparatus falls into two parts: (1) analysis of the tolerance time, which may be considered as a gross measurement of ability to work in these hot environments; and (2) analysis of physiological responses.

(1) Tolerance Times.—Individual tolerance times for men in the various saturated environments are shown in Fig. 1. There was a distinct difference in the tolerance times due to the type of breathing apparatus worn by the subjects, and it was therefore necessary to construct separate graphs. Also shown in Fig. 1 are lines representing the calculated 90% confidence limits of tolerance for each apparatus. Only 10% of men would be expected to exhibit a tolerance time shorter than that indicated by the curves.

The observers considered that in most of the 108

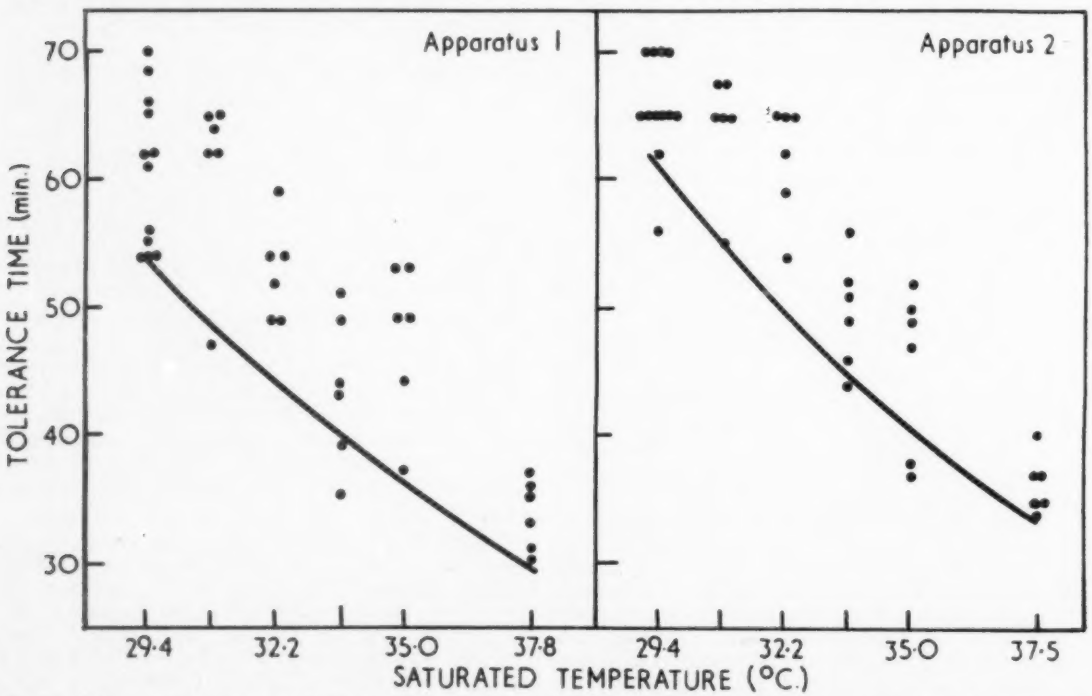

FIG. 1.—Tolerance times of men performing a " mines rescue task " in various saturated environments. Only 10% of men would be expected to have tolerance times shorter than those indicated by the continuous lines.

individual experiments the subjects left the chamber in a similar condition, as far as could be judged subjectively. The exceptions to this were, first, eight experiments at the two lowest temperatures where the men completed the 65-minute task without achieving the agreed end-point of 38·8° C. rectal temperature, and it was estimated that of the eight men five could have continued for a further five minutes, and three for a further 10 minutes; and secondly, one man in the 32·2° C., and a second in the 35° C., saturated environment were in a state of incipient collapse when they left the chamber, both displaying facial pallor and complaining of dizziness, slight nausea, and abdominal discomfort. It was considered that the remainder of the subjects would have been in a state of distress after about a further five minutes of the heavy work.

Table 1 shows the mean tolerance times for each age group, for each occupational category, and for the two types of breathing apparatus. Examination of the data reveals no significant difference due to age or occupation, but there is a significant difference (at the 1% level) due to the type of apparatus worn.

TABLE 1

MEAN TOLERANCE TIMES (MIN.) FOR TWO AGE GROUPS (18 MEN EACH), THREE OCCUPATION GROUPS (12 MEN EACH), AND TWO APPARATUS GROUPS (18 MEN EACH) AT VARIOUS SATURATED ENVIRONMENTS (°C)

Environment (°C)	29·4	30·8	32·2	33·6	35	37·8
Age Group						
Younger	63	65	57	50	45	36
Older	70	63	57	44	48	34
Occupation Group						
"Severe"	65	66	55	46	46	35
"Mixed"	64	59	58	46	46	36
"Deputies"	70	66	59	48	48	34
Breathing Apparatus						
Apparatus 1	62	62	53	44	48	34
Apparatus 2	71	66	62	50	46	36

In a separate test (to be reported elsewhere) all the subjects were exposed for four hours to conditions of dry-bulb 43·3° C. (110° F.) and wet-bulb 29·4° C. (85° F.), and carrying out intermittent work but without wearing breathing equipment. Analysis of these "uniformity" trials failed to show any difference in any of the physiological measurements between the two groups of men who wore the two different types of breathing apparatus in the present series of experiments. The significant difference in tolerance times between these groups is therefore not attributable to any peculiar difference between the men themselves but to the different types of apparatus worn.

(2) Physiological Observations.—Due to the severe environments and the nature of the work routine, most of the information common to all experiments relates to the first 30 minutes of exposure, but it has been possible to make some comparisons over longer periods.

Age.—There was no detectable difference in tolerance times of men of the two age groups. Rectal temperature increments in all six environments over the first 30 minutes, shown in Table 2, were significantly greater at the 5% level in the men of the older group. This estimate includes the two most severe environments where little or no difference was observed. Increments in pulse rates over this period of 30 minutes did not, however, differ significantly between the two age groups.

TABLE 2

INCREMENTS IN RECTAL TEMPERATURES (°C.) AND IN PULSE RATES PER MIN. AFTER 30 MINUTES' EXPOSURE FOR TWO AGE GROUPS OF 18 MEN EACH

Environment (°C.)	29·4	30·8	32·2	33·6	35	37·8
Rectal Temperature						
Younger	0·37	0·37	0·34	0·46	0·80	1·17
Older	0·44	0·52	0·46	0·74	0·80	1·05
Pulse Rate						
Younger	61	47	62	48	76	69
Older	38	47	50	60	70	87

Over the first 30 minutes, systolic pressures rose, while diastolic pressures remained unchanged (so that pulse pressures increased) in both groups (Table 6) but there was no difference between the age groups.

Sweat losses were assumed to be the simple loss in nude weight from the start to the end of the experiments. For the purpose of comparison only those experiments where men have worked for the same length of time in the same environmental conditions can be used. The only temperatures at which a sufficient number of men exhibited the same tolerance times were at 29·4 and 30·8° C., where over half of the men exposed completed the 65-minute task. At 29·4° C. there were 13 results from the younger group and 14 from the older group, and four of these in each group represented repeated exposures. At 30·8° C. there were nine results from each group, of which four and three were repeated exposures in the younger and older groups respectively. The means are shown in Table 3. There appears to be a tendency for the younger men to sweat more than the men in the older group, but the difference is not significant.

TABLE 3

MEAN SWEAT-LOSS DATA (g./m².hr.) IN TWO AGE GROUPS OVER COMPARABLE PERIODS OF EXPOSURE AT SEPARATE SATURATED ENVIRONMENTS

Temperature (°C.)	29·4	30·8
Younger	446	472
Older	375	405

The sweat losses on the first and second visits of the teams which were exposed on two occasions to the same environments were compared. The data are limited since only those results where men had exactly the same tolerance time on both occasions were comparable. The results are given in Table 4, and it can be seen that the sweat losses of all the younger men decreased on their second exposure (significant at 1% level), while the older group displayed no set pattern of behaviour, some increasing and some decreasing their sweat loss on the second exposure. These findings appear to show that the subjects did not acquire acclimatization to heat in the course of the investigation, for if acclimatization had occurred sweat losses would have increased. The younger men may have increased the efficiency of their work and this might account for the reduction of sweat losses on the second exposure.

TABLE 4

CHANGES IN AMOUNT OF SWEAT PRODUCED ON TWO OCCASIONS (g./m².hr.) IN MEN EXPOSED TO SAME CONDITIONS FOR SAME TIME

Team 1 (29·4°C.)		Team 2 (30·8°C.)	
Younger	Older	Younger	Older
—	—	−34	—
—	+24	—	+81
—	+56	−98	—
−83	+59	−35	+58
−54	−40	− 6	+ 1
− 7	−38	−48	− 4

Occupation.—There were no detectable differences in tolerance times due to the type of occupation normally pursued by the subjects.

Analysis of the mean rectal temperature increments over the first 30 minutes showed that the deputies, though they display no difference in tolerance times, have a significantly lower increment at the 5% level than either of the other two groups, which do not differ from each other (Table 5). The reason for this is not readily apparent.

TABLE 5

MEAN RECTAL TEMPERATURE INCREMENTS (°C.) DURING FIRST 30 MINUTES FOR EACH OCCUPATION GROUP OF 12 MEN

Environment °C. ..	29·4	30·8	32·2	33·6	35	37·8
"Severe"	0·45	0·54	0·47	0·60	0·88	1·10
"Mixed"	0·46	0·50	0·36	0·63	0·96	1·20
"Deputies"	0·31	0·50	0·38	0·57	0·55	1·03

No significant effects due to occupation were found in the data on pulse rates, blood pressures, or sweat losses.

Apparatus.—As already mentioned, there is a large difference in tolerance time due to the type of apparatus worn (Fig. 1). Men wearing apparatus 2 are able to continue the rescue task for a longer time than those wearing apparatus 1. These differences are associated with differences in the inspired-air temperature. A detailed comparison of these two forms of rescue apparatus has been presented in another paper (Lind, 1955), and need not be considered any further here.

Environments.—The first 30 minutes of moderate work (170 kcal./m².hr.) can be performed by all the men even in the most severe temperature conditions of this investigation, namely at 37·8° C. of the saturated air. As soon as the men change to the harder work, as is often required in rescue operations, the effect of the environmental conditions on their tolerance becomes very noticeable, as is shown in Fig. 1. From the maximum performance time of 65 minutes at 29·4° C. of saturated air there is an average fall of about 15 minutes for every 5° C. rise of wet-bulb temperature with apparatus 1 and 18 minutes with apparatus 2. The exact relationship between external temperature and tolerance time is probably a sigmoid curve, but these average values represent approximately a linear fall in tolerance time over the range of the environments in the present study.

Although the first 30 minutes of work are relatively easily tolerated, the body temperature even during this first period cannot be maintained at a steady level in saturated environments at temperatures above 32·2° C. (Fig. 2) and this is associated with a marked falling off in tolerance time (Fig. 1).

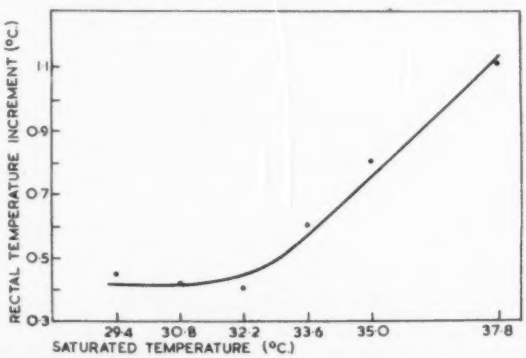

FIG. 2.—The relationship between saturated temperature (° C.) and rectal temperature increment (° C.) in the first 30 minutes of work at a mines rescue task.

A similar result appears when the pulse rates are considered. Fig. 3 shows the mean pulse rates for the complete exposure at each environment and here again there appears to be a progressive increase which becomes more marked when the temperature of the saturated air exceeds 32·2° C. It is interesting

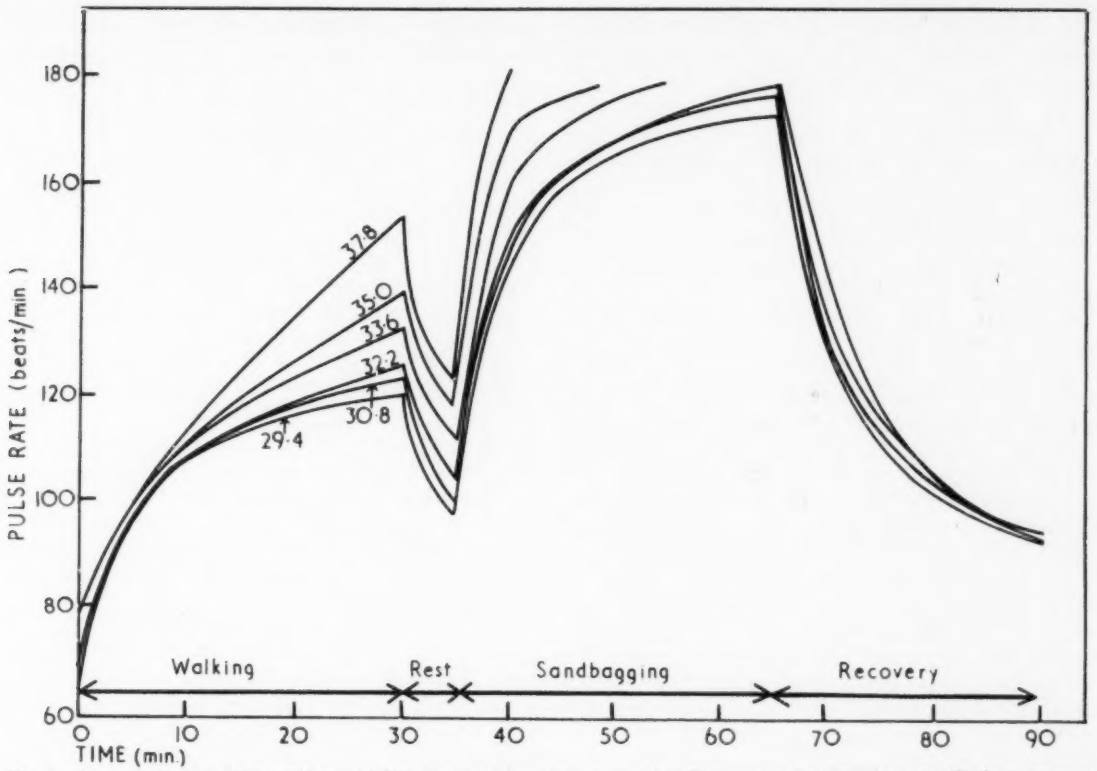

FIG. 3.—Mean pulse rates of men working at a mines rescue task in various saturated environments (° C.) throughout the 65-minute exposure to heat, and the 30-minute recovery period.

to note how extremely similar are the recovery curves for pulse rates irrespective of the duration of exposure or the environmental conditions during the exposure. This is added support for the belief that the men had attained a roughly similar end-point at the time of withdrawal from the heat.

Craig and others (1954) found a close correlation between the tolerance time and the time taken for the pulse rate to reach 160 beats/min. Such a correlation is not apparent in the present series, no doubt because the pulse frequently rose to the maximum countable rate soon after the beginning of the heavy-work period even at the lower environmental temperatures, and this " maximum " rate tended to be maintained until the end of the endurable exposure.

Blood pressures, taken over the first half-hour in the heat, show a definite tendency for systolic pressure to rise, although there was little change in diastolic pressure so that the pulse pressure also increases. The increment of pulse pressure (Table 6) tends to be enhanced after the environment has reached 32·2° C. Individual variation is, however, very large.

TABLE 6

CHANGES IN MEAN SYSTOLIC AND DIASTOLIC PRESSURES AND PULSE PRESSURE AFTER 30 MINUTES' WORK IN VARIOUS SATURATED ENVIRONMENTS

Temperature (°C.)	Blood Pressure (mm.Hg)			Pulse Pressure (mm.Hg)		
	Initial	After 30 min.	Change	Initial	After 30 min.	Change
29·4	123/84	138/87	15/3	39	51	12
30·8	121/83	137/88	16/5	38	49	11
32·2	121/83	141/87	20/4	38	54	16
33·6	122/82	153/92	31/10	40	61	21
35·0	122/83	140/82	18/–1	39	58	19
37·8	122/82	157/82	35/0	40	75	35

Discussion

The importance of giving captains of mines rescue teams guidance as to the (physiologically) permissible time available to them for carrying out rescue tasks needs no stressing. To do this it is necessary to think of the team as a whole and to allow a safety margin which will take account of the " weakest link ". We have accordingly proposed for underground emergencies time limits shorter by 10 minutes than the 90% confidence lines shown in Fig. 1. These recommended limits should provide

for all but the most heat-intolerant individuals, though such men, it is hoped, will be eliminated in a heat test during the periodic training course.

The only information at all comparable with that reported here is that by Roantree derived from systematic observations of men fighting underground fires in the Kolar Gold Field. On the basis of such observations over a wide range of thermal conditions Roantree has prepared a " predicted " curve relating length of shift to wet-bulb temperature. Though the time limits he suggests are only some five minutes longer than our average observed values, they exceed our recommended limits by 15 minutes at 90° F. wet-bulb and 10 minutes at 100° F. wet-bulb temperature. These differences are quite reasonably attributable to the state of natural heat acclimatization of his subjects, and probably also to the elimination of heat-intolerant subjects in the course of their ordinary mining work in consequence of the high temperatures prevailing in the Mysore mines (Caplan, 1950). None of our 36 subjects could be said to have experienced even moderately high temperatures during their ordinary mining occupations over the last two years or more. This emphasizes the necessity of allowing a safety factor, for it must be accepted that rescue men in this country at the present time, while of very high morale and well trained, are in general quite unacclimatized to heat.

Other situations where tolerance times to heat have been determined are those investigated by Craig and others on men working in protective clothing, and by Blockley and Taylor (1950) and Blockley and Lyman (1950) whose subjects were exposed to high external radiant heat. These authors have summarized their findings in the form of a relationship between the rate of heating up of the body (" storage ") and the tolerance time. The average tolerance of Blockley and Taylor's subjects for a given rate of "storage" was longer than that of Craig and others, but this is probably to some extent due to a difference in judging the termination of the exposure, for there is some overlap in individual values of the two series. In the experiments reported here it was not possible to follow the skin temperature so that " storage " could not be calculated, but from some recent experiments (to be reported elsewhere), in which we were able to record skin temperatures, it seems safe to conclude that the tolerance times of our subjects in relation to the rate of " heating-up " conform quite well to those of the American workers.

There is very little information in the literature on the effect of ageing on performance in the heat. The present investigation has not given any grounds for making a distinction in our recommendations between trained rescue personnel of the two age groups investigated. To support this we may quote the recent paper by Lavenne and Belayew (1954) who report that prolonged exposure to heat *per se* does not increase the frequency of cardiac disorders in older mine workers. We have found, however, some small but detectable differences in physiological response between our two age groups. The older men in the first 30 minutes of exposure showed a somewhat greater rise in rectal temperature, and over a period of 65 minutes have a tendency to sweat less. This delay in heat-regulatory response on the part of the older men, slight though it is, was evident also in the " uniformity " trial referred to previously.

Mackinnon (1954) claims that the number of active sweat glands is markedly reduced with age. On the basis of her findings, we might expect a reduction of about 30% in the number of active glands from the younger to the older groups of subjects in our experiments. The observed reduction in sweat loss is, however, only about 15% (and this does not reach even the 10% level of significance). Mackinnon's sweat gland counts were confined to the palmar surface of the finger, where emotion influences sweating far more than does a thermal stimulus (Kuno, 1934 ; Weiner, 1945) and her results may therefore not be applicable to sweat glands in general. That men of 45 possess fewer active glands, each gland working at a higher average rate, remains a possibility, but this requires further investigation.

Summary

Thirty-six mines rescue personnel wearing self-contained breathing apparatus were exposed to a stipulated work routine in various saturated environments, and their " tolerance times " were determined.

There was no demonstrable difference in tolerance time of men in two age groups (19–31 and 39–45 years) although minor physiological differences were detected.

No difference was found in the ability of men in three occupational groups to work in saturated environments.

The use of the information on " tolerance times " as it affects the mines rescue service is discussed.

We wish to thank the National Coal Board, and in particular the Rescue Service of the National Coal Board, who provided administrative and experimental facilities. We are also indebted to the 36 subjects without whose whole-hearted cooperation these experiments would not have been possible.

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APPENDIX

Details of the Rectal Thermocouple Used in the Experiments

BY

R. F. HELLON

There appears to be no description in the literature of a reliable and comfortable rectal thermocouple which may be used on untrained subjects. No originality is claimed for the use of an indwelling thermocouple for taking rectal temperatures, but it was felt that details of its construction would be of interest.

Construction

The thermal junction was made of 30 s.w.g. copper-constantan covered with plastic to form a flat twin-flex. It was soldered within a thin-walled brass cap 5·6 mm. outside diameter and 5 mm. long. A 7 cm. length of 22 s.w.g. piano wire was taped to the plastic covering just behind the cap and the whole was placed in a specially made glass mould. After filling the mould with polyvinylchloride paste by oral suction and baking at 150° C. for 10 minutes, the finished rectal thermocouple was removed by carefully smashing the glass mould (Fig.4).

The thermocouple was inserted into the rectum by means of a brass pusher, so that the bulb lay just beyond the anal sphincter. The pusher was then withdrawn along the lead.

Conduction Errors

Using a thermocouple 8 cm. in length and with 2 cm. of lead in the anal canal, the thermal junction itself was about 10 cm. from the exterior. If the air temperature was much different from the temperature in the rectum, then conduction along the lead could conceivably influence the thermocouple. In order to ascertain the probable magnitude of this effect, a rectal thermometer was placed in a vacuum flask completely filled with water at about body temperature. Two cm. of lead passed through the cork (corresponding to the anal sphincter) and the next 40 cm. were formed into a tight coil. Placing the coil in crushed ice or water at 52° C. caused changes in the recorded temperature of less than 0·1° C. (Fig. 5). The conduction error caused by air at 0° C. or 52° C. would be less than this owing to the low specific heat of air.

Advantages

The thermocouple always remains a fixed distance within the rectum. It is comfortable to wear, even for untrained subjects for periods up to four hours at least, and no external fastening is necessary. Since only the flexible lead passes through the anal canal, the wearer may sit or perform vigorous exercise with no discomfort.

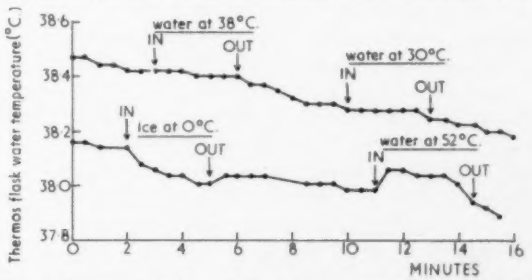

FIG. 5.—Effect of placing 40 cm. of the thermocouple lead in water at various temperatures on the temperatures recorded by the thermocouple.

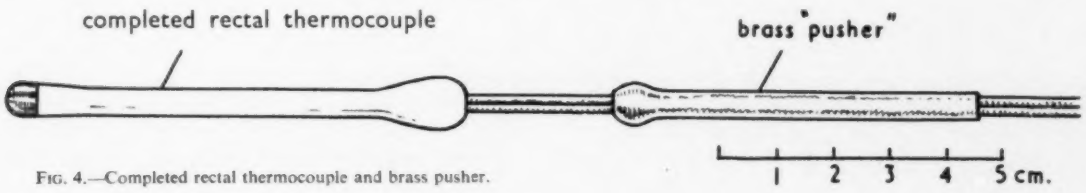

FIG. 4.—Completed rectal thermocouple and brass pusher.

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APPENDIX

Details of the Rectal Thermocouple Used in the Experiments

BY

R. F. HELLON

There appears to be no description in the literature of a reliable and comfortable rectal thermocouple which may be used on untrained subjects. No originality is claimed for the use of an indwelling thermocouple for taking rectal temperatures, but it was felt that details of its construction would be of interest.

Construction

The thermal junction was made of 30 s.w.g. copper-constantan covered with plastic to form a flat twin-flex. It was soldered within a thin-walled brass cap 5·6 mm. outside diameter and 5 mm. long. A 7 cm. length of 22 s.w.g. piano wire was taped to the plastic covering just behind the cap and the whole was placed in a specially made glass mould. After filling the mould with polyvinylchloride paste by oral suction and baking at 150° C. for 10 minutes, the finished rectal thermocouple was removed by carefully smashing the glass mould (Fig.4).

The thermocouple was inserted into the rectum by means of a brass pusher, so that the bulb lay just beyond the anal sphincter. The pusher was then withdrawn along the lead.

Conduction Errors

Using a thermocouple 8 cm. in length and with 2 cm. of lead in the anal canal, the thermal junction itself was about 10 cm. from the exterior. If the air temperature was much different from the temperature in the rectum, then conduction along the lead could conceivably influence the thermocouple. In order to ascertain the probable magnitude of this effect, a rectal thermometer was placed in a vacuum flask completely filled with water at about body temperature. Two cm. of lead passed through the cork (corresponding to the anal sphincter) and the next 40 cm. were formed into a tight coil. Placing the coil in crushed ice or water at 52° C. caused changes in the recorded temperature of less than 0·1° C. (Fig. 5). The conduction error caused by air at 0° C. or 52° C. would be less than this owing to the low specific heat of air.

Advantages

The thermocouple always remains a fixed distance within the rectum. It is comfortable to wear, even for untrained subjects for periods up to four hours at least, and no external fastening is necessary. Since only the flexible lead passes through the anal canal, the wearer may sit or perform vigorous exercise with no discomfort.

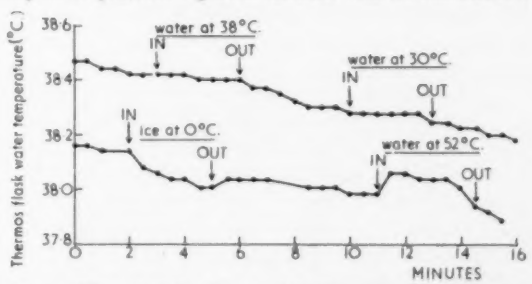

FIG. 5.—Effect of placing 40 cm. of the thermocouple lead in water at various temperatures on the temperatures recorded by the thermocouple.

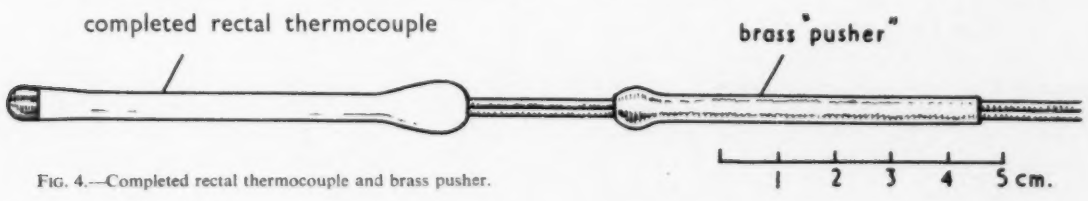

FIG. 4.—Completed rectal thermocouple and brass pusher.

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THE FORMATION OF PHOSGENE BY THE ACTION OF HOT SURFACES AND ITS ABSENCE WHEN TOBACCO IS SMOKED IN ATMOSPHERES CONTAINING CHLORINATED HYDROCARBON VAPOURS

BY

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When trichloroethylene or certain other solvent vapours are heated to a temperature of 400° C. or more, or when the liquids decompose by exposure to light on standing in air, phosgene is produced. It is generally believed or assumed from this that when cigarettes are smoked in atmospheres contaminated with the solvent vapours phosgene is also produced and inhaled. However, nowhere in the literature is experimental evidence given of phosgene being positively identified in the inhaled gases from a cigarette smoked in these contaminated atmospheres although the danger has been pointed out by several writers, including McNally (1937), Oettingen (1937), and Converse (1938). A secondary danger may exist from the glowing cigarette tip in the atmosphere around the cigarette.

Elkins and Levine (1939) carried out a comprehensive series of tests in which the effluent from cigarettes smoked in atmospheres containing a number of halogen-containing hydrocarbon vapours was examined. They did not test the inhaled gases specifically for phosgene, but, on the basis of the halide content of the exit gases, calculated that even if all the halogen found was so present it would not constitute a health hazard.

The tolerance limit for continual exposure to phosgene in the atmosphere is stated by Patty (1949) to be 1·0 part per million by volume, a concentration of 2 parts per million being dangerous for prolonged exposure.

In view of the extremely toxic nature of phosgene, therefore, it is essential that smoking in the presence of these solvents be forbidden unless it can be demonstrated by a test of adequate sensitivity that phosgene is not present in the exhaled tobacco smoke or formed in the surrounding atmosphere.

The Detection of Phosgene

Phosgene in the atmosphere may be detected by means of a coloration produced when the atmosphere is brought into contact with the mixed reagent, *p*-dimethylaminobenzaldehyde and diphenylamine. The standard method used for testing described by the Department of Scientific and Industrial Research (1939) uses a paper disc impregnated with this reagent. The atmosphere is drawn through the paper at a prescribed rate by means of a hand pump until a standard coloration is produced. The volume of atmosphere drawn through is a measure of the phosgene content, which is read from a table. This test was used to obtain the results given in Table 2. The test is sensitive down to about 0·5 parts per million, which is about the tolerance limit for phosgene.

It has been found that when the reagent is deposited on glass ground to coarse powder and the test applied by drawing the atmosphere through a narrow glass tube containing the glass powder impregnated with the reagent, then the sensitivity is increased at least tenfold and a concentration of phosgene of 0·05 parts per million by volume may be detected. Glass powder which passes between sieves 25–36 B.S. mesh was found to be most suitable ; a narrow tube, internal diameter 6 mm., was used, the reagent column length being about 10 cm. The test may be made approximately quantitative by comparison with coloured glass in a tube. A suitable reference colour is obtained by washing glass powder in a solution of 10 mg. of " waxoline yellow " in 100 ml. alcohol, then drying off the alcohol in a downward stream of nitrogen. The results given below are referred to this colour standard.

The colour produced by phosgene is proportional to the volume of the atmosphere drawn through the tube, but is also dependent on the rate at which the atmosphere is drawn through. Table 1 gives results obtained by drawing the atmosphere through the tube at a gas rate of 30 litres per hour, which is the rate used in the subsequent smoking experiments.

TABLE 1

DETERMINATION OF PHOSGENE IN ATMOSPHERE BY COMPARING COLOUR PRODUCED IN AN INDICATOR TUBE WITH AN ARBITRARY COLOUR STANDARD

Concentration of Phosgene in the Atmosphere (p.p.m.)	Volume of Gas drawn to Match the Standard Colour (litres)	Time Taken to Match the Standard Colour (minutes)
0·05	6	12
0·20	1½	2½
0·50	¾	1
1·0	¼	½

The standard colour at this flow rate is equivalent to about 1 μg. of phosgene.

Formation of Phosgene by Pyrolysis

When atmospheres containing the vapours of chlorine-containing hydrocarbons are exposed to hot surfaces at temperatures greater than 400° C., decomposition takes place with the formation of phosgene. The results quoted in Table 2 were obtained by drawing air containing the solvent vapour through a silica tube. The silica tube was packed with silica lumps and heated to the stated temperature over a length of 6 in. All the results were obtained from the same experimental conditions and hence it is possible to obtain from them a rough idea of the relative stability of the vapours.

TABLE 2

COMPARISON OF AMOUNTS OF PHOSGENE FORMED WHEN ATMOSPHERES CONTAINING VARIOUS CHLORINATED HYDROCARBON VAPOURS ARE PASSED THROUGH A HEATED SILICA TUBE UNDER CERTAIN STANDARDIZED CONDITIONS

	Vapour Concentration (%v/v)	Phosgene Produced at Stated Temperature (parts per million)				
		400°C	500°C	600°C	700°C	800°C
Methylene chloride	0·5	N.D.	<1	<1	3	20
Chloroform	0·4	<1	15	130	—	—
Carbon tetrachloride	0·4	N.D.	7	25	—	—
Dichloroethylene (sym. cis.)	0·5	N.D.	4	50	—	—
Dichloroethylene (sym. trans.)	0·6	N.D.	N.D.	3	20	—
Trichloroethylene	0·3	N.D.	2	30	—	—
Perchloroethylene	0·3	N.D.	N.D.	1	10	—
Ethylene dichloride (sym.)	0·12	N.D.	N.D.	3	5	15
Tetrachloroethane (sym.)	0·3	N.D.	1	7	—	—

N.D. = not detected. The limit of detection in this case was 0·5 p.p.m.

Application of the Test for Phosgene to the Exhaled Gas from Cigarettes Smoked in the Contaminated Atmosphere

The physical characteristics of normal smoking have been discussed by Bradford, Harlan, and Hanmer (1936) and by Pfyl (1933). For the experiments described in this paper a continuous smoking rate of 30 litres per hour was decided upon. This is less than the peak rate in normal puffing, but considerably greater than the average rate of inhalation.

In order to apply the test for phosgene to the exhaled gases from the cigarettes it is first necessary to remove the smoke component, which is in fact a tarry mist consisting of a variety of organic substances. This is most easily accomplished by means of a jet scrubber, in which the smoke impinges against a glass surface through a narrow annular space.

The cigarette was fitted into a glass holder inside a wide glass tube, through which the prepared atmosphere was passed, the cigarette tip being lightly smeared with silicone grease to make the joint air-tight. The atmosphere was drawn through by means of a water pump, the rate of flow, controlled by an air leak, being indicated by a flow meter. The apparatus consisted of the smoking chamber, the jet scrubber to remove the tar, the indicator tube and the water pump and flow meter. The pressure drop through the apparatus, which progressively increased during smoking, was measured by means of a simple manometer, and a predetermined correction was applied to the flow rate indicated to maintain the required flow rate calculated to atmospheric pressure.

Atmospheres containing the solvent were prepared by passing a measured stream of air through a sintered glass bubbler containing the liquid into a second stream of uncontaminated air, the concentration of vapour obtained under the set condition (temperature, flow rates, etc.) being calculated from the vapour pressures of the solvents. Atmospheres containing phosgene were prepared from a cylinder containing pure phosgene, the phosgene being bled into a measured flow of air through a calibrated bubbler containing concentrated sulphuric acid. Atmospheres containing down to 10 parts per million by volume of phosgene were prepared by a single dilution; atmospheres containing down to 0·05 parts per million were obtained by a second dilution.

Smoking experiments were made in atmospheres containing trace concentrations of solvent vapours. In no case was phosgene detected, the limit of detection being 0·05 parts per million by volume.

However, it was found that even when cigarettes were smoked in atmospheres which contained phosgene, phosgene was not detected in the effluent. Neither was phosgene detected when, after smoking, the stub was removed from the holder and the phosgene-containing atmosphere continued to be drawn through the empty holder. It was subsequently found that in this apparatus containing the tar from a single cigarette, an atmosphere containing 50 parts per million by volume of phosgene could be drawn through for about 20 minutes at the experimental smoking rate of 30 litres per hour before even a trace of phosgene was detected. The smaller amounts of phosgene combined effectively with the tar. This absorption of phosgene by the tar is not a simple physical solution since the phosgene absorbed cannot subsequently be displaced into a stream of air, and is probably chemically combined with the tar to form a new compound.

The conclusion to be drawn from these experiments is that phosgene, if formed, is unlikely to survive through a lighted cigarette. There remains, however, the possibility that the phosgene may not be entirely absorbed within the cigarette. In order to relate the experimental results to normal smoking in which the emergent gases from the cigarette pass immediately into the mouth, the test must either be applied at the point of emergence of the smoke from the cigarette, which is impracticable, or the capacity of the tar leaving the cigarette to absorb phosgene must be eliminated.

The absorption of phosgene by tobacco tar is probably due to basic organic substances in the tar. It was found that when the tar deposited in the apparatus was acidified by a stream of hydrogen chloride vapour it was no longer an avid absorbent of phosgene. Only a slight residual absorption remained; for example, the colour test obtained from 0·2 parts per million by volume of phosgene was obtained in about four minutes using the same flow conditions as were used to obtain the values given in Table 1. The hydrogen chloride, to which the indicator is also highly sensitive, was conveniently removed by including a tube containing pumice granules loaded with a mixture of sodium thiosulphate, sodium iodide, and potassium iodate before the indicator tube. A trace of hydrogen sulphide was evolved from the acid absorbent but this was removed by also including a tube containing lead acetate granules.

This procedure was applied to the smoking experiments. A stream of the hydrogen chloride was passed through a fine tube into the cigarette holder to mix with the smoke emerging from the cigarette.

In the experiments, usually five cigarettes were smoked in succession, at the prescribed flow rate. Hydrogen chloride was introduced into the exit gas from the cigarettes at a sufficient rate to provide a slight excess of acid, which passed through into the pumice absorbent forming a brown stain at the beginning of the tube. The cigarettes were smoked completely through except in the experiments where phosgene was added to the smoked atmosphere, and in these instances the cigarettes were smoked down to a stub length of about half an inch.

In all the tests applied, only a trace colour was produced in the indicator tube during smoking. This trace colour, obtained equally from smoking in a pure atmosphere and in a contaminated atmosphere, indicated a phosgene level not greater than 0·1 parts per million. This "blank" colour was obtained even when a tube containing sodium hydroxide granules was included before the indicator tube and was therefore not due to phosgene. However, because of the formation of this trace "blank" colour the limit of detection of phosgene is raised to 0·1 parts per million. Results obtained are summarized in Table 3.

TABLE 3

DETECTION OF PHOSGENE IN INHALED GASES FROM CIGARETTES SMOKED IN ATMOSPHERES CONTAMINATED WITH CHLORINE-CONTAINING HYDROCARBON VAPOURS

Solvent	Concentrations of Solvent Vapour in the Atmosphere (p.p.m. v/v)	Phosgene in the Inhaled Gases (p.p.m. v/v)
Trichloroethylene ..	2000	Less than 0·1
Trichloroethylene ..	200	" " 0·1
Tetrachloroethane ..	10	" " 0·1
Chloroform	300	" " 0·1
Carbon tetrachloride ..	50	" " 0·1
Perchloroethylene ..	200	" " 0·1
Phosgene	20	" " 0·1
Phosgene	0·2	" " 0·1

Application of the Test for Phosgene to the Atmosphere Surrounding the Cigarette

The presence of a glowing cigarette tip in an atmosphere containing the solvent vapour might be expected to produce phosgene in the surrounding atmosphere, but the formation would depend upon the conditions around the tip, such as the presence of tobacco tar in the evolved smoke and the turbulence of the atmosphere. Phosgene, if formed, would be rapidly dissipated in the surrounding atmosphere and the principal hazard would be to the smoker. Another hazard would result from, possibly several, cigarette stubs smouldering in an ash tray.

During inhalation of air at the rate of 30 litres per hour, the cigarette glow is continuous and only a small amount of smoke rises from the tip. In normal smoking, where the inhalation is discontinuous, the smouldering cigarette evolves a greater

amount of smoke. The temperature of the glowing tip during inhalation is about 950° C. falling to about 700° C. in the smouldering condition.

In normal smoking, contact between the atmosphere and the glowing cigarette tip is mainly due to simple convection and diffusion. Induced movement of the atmosphere around the tip would be more favourable for the formation of phosgene and a satisfactory condition to apply in the present experimental investigation. A sampling technique should not, however, create too great an air flow since this would have a cooling effect on the tip. The standard rate of 30 litres per hour was considered to be a satisfactory rate of sampling for the experiments.

In the experiments made to examine the surrounding atmosphere, the cigarette was fixed into a vertical holder inside a wide glass smoking chamber, through which the prepared atmosphere was passed. The cigarettes were smoked at the rate of 30 litres of air per hour and the test was made by drawing the atmosphere from around the cigarette tip through the indicating tube, also at the rate of 30 litres per hour, as stated above. The prepared atmosphere was passed through the smoking chamber at a rate of about 70 litres per hour. The test for phosgene was applied directly to the atmosphere in the vicinity of the smoked cigarette tip and, even in the smouldering condition, the indicating granules were only slightly discoloured brown by the smoke. The brown colour was distinctly different from the yellow colour due to phosgene.

A preliminary experiment was made by smoking in an atmosphere which contained 20 parts per million phosgene. When the atmosphere was drawn from near the glowing tip, but out of contact with the rising smoke, a coloration equivalent to the 20 parts per million was obtained, but when the atmosphere was drawn from above the glowing cigarette in the path of the evolved smoke a diminished coloration was obtained. In a second preliminary experiment when the prepared atmosphere contained one part per million phosgene, the phosgene could not be detected in the atmosphere in contact with the evolved smoke.

Experiments were made by smoking in atmospheres contaminated by the solvent vapours. In no case was phosgene detected. The results are given in Table 4. The atmosphere was drawn from two positions within the smoking chamber, from a position $\frac{1}{2}$ in. to the side of the glowing tip, and from a position about 2 in. above the tip, directly in the path of the rising smoke. Two cigarettes were smoked for each test, the time taken being four minutes. The standard colour under these conditions would represent about 0·1 parts per million phosgene. The limit of detection of the test applied, therefore, is better than 0·1 parts per million.

TABLE 4

DETECTION OF PHOSGENE IN THE ATMOSPHERE AROUND CIGARETTES SMOKED IN ATMOSPHERES CONTAMINATED WITH CHLORINE-CONTAINING HYDROCARBON VAPOURS

Solvent	Concentration of Solvent Vapour on the Atmosphere (p.p.m. v/v)	Phosgene Adjacent to the Cigarette Tip (p.p.m. v/v)	Phosgene Above the Cigarette Tip (p.p.m. v/v)
Trichloroethylene	200	Less than 0·1	Less than 0·1
	2000	,, ,, 0·1	,, ,, 0·1
Chloroform ..	300	,, ,, 0·1	,, ,, 0·1
	2000	,, ,, 0·1	,, ,, 0·1
Carbon tetrachloride	50	,, ,, 0·1	,, ,, 0·1
	2000	,, ,, 0·1	,, ,, 0·1
Perchloroethylene	200	,, ,, 0·1	,, ,, 0·1
	2000	,, ,, 0·1	,, ,, 0·1

The results given are based on atmospheres drawn from around the tip at the rate of 30 litres per hour.

Conclusion

When atmospheres containing the vapour of certain chlorine-containing hydrocarbons are exposed to hot surfaces at temperatures greater than 400° C. decomposition takes place with the formation of phosgene. The concentration of phosgene which may accumulate in the neighbourhood of hot surfaces will naturally depend on a variety of conditions, including the concentration of the solvent vapour in the atmosphere and the temperature of the hot surface.

Phosgene is not found in the vicinity of the glowing tip of a cigarette smoked in the contaminated atmospheres and even when a trace of phosgene is added to the atmosphere it rapidly decomposes in the presence of the evolved smoke. The limit of detection of phosgene in the atmosphere by the test applied is 0·1 parts per million by volume, but even if this concentration were present, it would be rapidly dissipated in the surrounding atmosphere.

When cigarettes are inhaled in atmospheres contaminated with these solvent vapours phosgene is not detected in the exit gas. Even if phosgene is formed or is present at the ignited tip it does not survive through the cigarette. The limit of detection of phosgene in the cigarette exit gases by the experimental technique applied is also 0·1 parts per million by volume. Assuming that a man smokes a cigarette in five minutes and that his normal rate of respiration is 10 litres per minute, then only one fiftieth of the atmosphere breathed consists of the exit gases from the cigarette, hence even though the concentration of phosgene determined is less than 0·1 parts per million the maximum possible con-

centration of phosgene to which the man is exposed is 0·002 parts per million.

Summary

Comparative tests made by passing atmospheres containing certain chlorine-containing solvent vapours through a heated silica tube show that phosgene is formed when the surface temperature is greater than 400° C.

A test for phosgene in an atmosphere has been developed which can be applied to measure a concentration of 0·05 parts per million by volume.

An experimental technique has been devised to apply this test to determine the phosgene in the exit gas from the cigarette which is inhaled and in the atmosphere surrounding the glowing tip, when cigarettes are smoked in these solvent-contaminated atmospheres. In no case was phosgene detected and even when phosgene was added to the atmosphere it was destroyed by passage through the cigarette being smoked.

Part of the work reported here, especially the work on the decomposition by hot surfaces, was carried out by A. G. Trenery and J. Watt.

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OLDER PEOPLE AND HEAVY WORK

BY

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The proportion of older persons in the population is increasing year by year and, in anticipation of the economic consequences that this situation will bring about, growing support has developed for the proposal that more elderly people should be employed in industry. However, the prevalence of policies of age discrimination in labour intake and of compulsory retirement at fixed ages in many occupations suggests that opportunities for the employment of older people have not been developing at a rate commensurate with the need. Indeed, an inquiry carried out by Thomas (1947) for the Industrial Health Research Board reported :

> " A comparison with the census of England and Wales, 1931, reveals that, contrary to what might have been expected in view of the wartime demand for labour, a lower proportion of old persons over 60 was in employment in 1945 than in 1931."

Moreover, as the proportion of older people in employment declined steeply in the two years following the war (*Ministry of Labour Gazette*, 1948), there are some grounds for the conclusion of the report that . . . " even fewer old persons may remain in employment in the future ".

It is worth noting that a similar trend has been reported in the United States. While the number of persons aged 65 and over has multiplied by over four times in the past half century the proportion of employed men aged 65 and over has fallen steadily over the same period. In 1870 80% of the older men were working, in 1910 63%, in 1930 54%, and in 1940 41%. The percentage increased during the war but by 1950 it had declined to 45% (see Mushkin and Berman, 1947 ; Burns, 1954). A steady though less marked decline has also shown itself for employed men between 55 and 64. A Committee on Aging and Geriatrics (1952), in presenting information on this subject, has suggested that this decline is due in large measure to the shrinking place of agriculture and self-employment generally in the national economy.

If such an interpretation is correct and applies to similar trends in Great Britain the recommendation made by the National Advisory Committee on the Employment of Older Men and Women (1953) on the need to increase the proportion of older persons employed in industry is not likely to be easily accomplished. It would appear that the demands of industrial work are less suited to the capacities of older persons than other types of work. Moreover, the problem is rendered more difficult by the fact that there is no general agreement as to the type of industrial work which is most suited to older persons. The most commonly held view is that older people should be transferred to lighter work, but the implication that industrial work is not suited to older persons because of its heaviness should not be taken for granted. Whether or not lighter work can be recommended as a policy likely to increase the number of persons working in the higher age groups depends on a careful sifting of the facts. To present data relating to this subject is the object of the paper.

Previous Studies

The first serious and comprehensive study of the older worker in industry was made by Barkin (1933) in a report prepared for the New York Joint Legislative Committee on Unemployment. In one chapter on the " Characteristics of the Older Person as a Worker " Barkin presented data on the type of work in which people of different ages tended to be found in industry. Industrial work was divided into five main groups : hand work, body work, machine work, clerical work, and supervisory and technical work. Barkin observed :

> " The most striking fact presented by a study of the persons engaged at various types of work is that the percentage of persons at body work increased with advancing age, particularly after 35 years of age. While 21·3% of the persons 30–34 years were employed at such work, this percentage rose to 25·6 for the age group 40–44 years, to 28·7 for the age group 50–54 years, to 34·3 for the age group 60–64 years, and to 37·5 for the age group 70 years and over."

Body work was defined as " that type of work which is performed by the application of bodily

strength or by the use of large tools demanding bodily movements ". In a further analysis operations were divided into three grades according to the degree of physical exertion imposed—great, medium, and slight. The smallest percentage engaged on work requiring great physical exertion was the youngest age group (5·4%), the percentage increasing with each demi-decade up to 18 in the 40–44 age group and thereafter declining by not more than 1% per demi-decade up to the age group 70 and over where the percentage fell to 12·4. Even more striking were the results which Barkin obtained for those newly hired.

> " The group where the older person as a class possesses the greatest hold," he observed, " is that in which the job demands great physical exertion. Approximately 26% of all the persons hired for such jobs were 40 years and over. The others follow in inverse proportion to the degree of physical exertion which is needed. Twenty-five per cent. of the men added to jobs grouped as requiring medium physical exertion were beyond 40 years of age. The proportion, however, for those requiring slight physical exertion was only 15% . . . Among the women workers the largest percentage of older females hired in any one single class is also to be found in the jobs requiring great physical exertion (13·3). The other two classes follow in the same order as for the males, medium (12·6%) and then slight (9·7)."

These notable findings obtained during the years of the depression in the United States lead us to enquire how far similar tendencies exist in Britain in the post-war period when employment has been generally high. A simple answer, however, is not forthcoming as research investigators have not posed exactly the same questions as those of Barkin, but there is a certain amount of miscellaneous information which has a bearing on the type of work on which older people are employed and which relates in particular to the heaviness of the work. This information may be summarized as follows.

(1) Distribution of Older People between Different Industries.—Information relating to this subject has been presented by the Industrial Welfare Society (1950) and the National Advisory Committee on the Employment of Older Men and Women (1953). There appear to be no very marked differences as between different industries and there is no pattern that is associated with the differences in physical exertion which various industries may impose. For example, the percentage of persons employed in mining and quarrying aged between 55 and 64 is 14 and between 65 and 69 is 2·4 as against the national industrial average of 13·3 and 2·5 respectively. However, it is not known upon what jobs the older workers are actually engaged. The older workers might be employed on light work in " heavy " industry or relatively heavy work in " light " industry. The data can only be assessed if more is known about the different types of work which older people perform and their tendency to transfer from jobs which they have previously held.

(2) Distribution of Older People between Different Types of Work.—Thomas and Osborne (1950) persented data on the distribution of a sample of 1950 male workers between the ages of 55 and 74. Dividing the types of industrial operations into the categories of professional, higher technical, managerial, clerical, manipulative, operative, and unskilled, it was found that fewer of the older men than men of the general population were operative and manipulative workers, 25% and 14% respectively against 35% and 20% in the normal population, and more of them were unskilled, 22% as against 15%. Unskilled workers were defined for the purpose of the investigation as " all those whose physical strength enables them to carry out a task without training or the provision of tools other than the simplest hand tools ". In a sample of 482 women in the same age range 30% of the older women were classed as operatives as against 50% in the general population and 35% of the older women were unskilled workers as against 10% in the general population.

Except for the work of Richardson, to be considered below, there is little data specifically referring to heavy work. Two studies, however, contain some mention of the subject. When male manipulative workers, operatives, and unskilled workers between the ages of 55 and 74 were questioned in the study of Thomas and Osborne (1950) as to the type of work performed in their present or last full-time job, 18% stated that they had been engaged on very heavy work and a further 38% on moderately heavy work. Comparable figures for male workers over pensionable age, *i.e.*, over 65, were obtained in the survey carried out by the Industrial Welfare Society (1950). Replies from 349 firms showed that 17% of the elderly workers employed were engaged on heavy work, 48% on medium work, and 27% on light work. For female elderly workers of 60 years and over the figures were 1%, 38%, and 61% respectively. But what interpretation can be placed on the data is not clear. In neither study was heavy work defined nor were the data obtained compared with those of a control group of younger men.

(3) Transfer of Older People from One Form of Work to Another.—The rates at which older people retire from the building industry and the type of change of job to which they are subject in

later life have been studied by Le Gros Clark (1945a, 1945b, 1955). Failing health appeared to play an important part in such retirement. On the other hand moves to more amenable work in the 60s and 70s appeared to be fairly common irrespective of health. This usually involved, however, not so much a move to lighter work or a change in the type of work but rather a change to easier circumstances in which to carry out similar tasks. Thus the tendency is noted for older workers to engage in work which they can carry out at their own pace; for example, it is typical for older workers to engage in maintenance work rather than in constructional work. Most of the heavy work in the building industry is probably labouring. It is worth noting here, however, that the age wastage from labouring was not greater than for other building occupations.

Apart from the data included in Le Gros Clark's studies there are only two other investigations which were specifically concerned with job change with age. These are an earlier study by the writer (1953) and a study by Richardson (1953).

In the former study evidence was given that transfers tended to occur from the early 50s from operations which required continuous bodily movement and activity in association with a rapid tempo of work, accentuated by the payment of piece-rates or enforced by the requirements of a working team, a series of machines, or a conveyor-line. A few workers on these operations, however, were able to continue till the retiring age. On other operations older workers were rarely found to move to other work except where there were indications of failing health. Heaviness alone, *i.e.*, with no further strain imposed by the tempo of work, did not appear to cause moves with increasing age.

In Richardson's study workers between the ages of 50 and 79 were interviewed in two foundries and a coal-mine. They were asked a number of questions relating to their work history. One question asked was whether they had ever moved from heavy to light work. Those in the 70s were more inclined to say yes than those in the 60s and those in the 60s more than those in the 50s. From the replies as to the age at which such changes had occurred Richardson calculated the probabilities or rate of transfer to lighter work for different age groups. The rate per year was extremely low for the 20s, less than 0·01 in the 30s, rising to 0·05 in the 50s, and continuing to rise thereafter. Noting that national unemployment figures showed a sharp rise from the 40s onwards and finding an analogous tendency in his own data, Richardson reached the tentative conclusion " that the real trend of transference to lighter work is a low incidence until the 40s and a rapid rise from then on ". Richardson's data and conclusions are re-examined later in this paper.

Method and Results in Two Studies

The data to be presented in this paper are divided into two sections. The first is concerned with the age distribution of men and women employed on heavy work and therefore corresponds with **(2)** opposite. It is subdivided into two parts, one dealing with a small-scale sample of operations personally studied by the author and the other a more general analysis of occupations and ages listed in the 1951 census. The second section deals with an intensive study of job change in a firm which included an unusually large proportion of heavy jobs.

The Age Distribution of Men and Women Employed on Heavy Work

Evidence from a Small Sample.—Previous data obtained by the author on the distribution of ages for certain types of industrial operation have been presented elsewhere (Belbin, 1952, see also Welford, 1951). The operations studied were divided into the following categories: Heavy and active work, machine feeding, machine operating, light assembly, and inspection. There was no apparent tendency for a larger proportion of older men or women to be employed on any one of the various categories of operation.

Heavy and active work was defined as " operations involving considerable muscular effort in the handling of heavy materials " and included " those involving a high degree of activity which made them regarded as heavy in the factories concerned ". The latter group of operations tended to be those from which older people moved away before the age of retirement and has been described in detail in a previous paper (Belbin, 1953). These operations had the effect of lowering the age distribution for the heavy and active category.

Most of the active operations were not in fact heavy in the sense that they demanded muscular exertion. But they made demands on physical movement and speed. A separation here between " heavy " and " active " seems therefore desirable. When the active operations, *i.e.*, operations not requiring lifting or moving of heavy objects or other forms of work requiring physical exertion, are excluded from the heavy and active category there remain operations which are heavy in the sense that they require specifically lifting, moving around of heavy objects, and strenuous exertion. To this group may be added a few operations originally listed under the other categories of work

but which also possessed the characteristics of heaviness mentioned above. The total heavy group comprised: giant tyre casemaking, the manual assembly of the cover and tread of giant tyres before the process of moulding; hide shaving involving the lifting and moving around of hides weighing 20 lb. on a shaving machine; various operations involving the handling, stencilling, and loading into lorries of paint drums and cases (most of the drums weighing 42 lb. and some of the cases handled weighing as much as 120 lb.); the feeding of planks weighing approximately 50 lb. into planing and sawing machines; repolishing bearings, involving the frequent lifting of trays of over 50 lb. and the application of force in pressing rings against mechanical polishers; the setting up and operating of lace machines which involved lifting heavy mechanical parts without mechanical aids; the manual fitting of tyres on to car wheels; the handling of cylinder blocks in machine grinding; the rubbing down of cars with emery paper before cellulosing; the work of fitting in a large machine shop; plateworking in a heavy engineering firm, a number of foundry operations taken from two firms; packing and dispatching heavy boxes (weighing up to 120 lb.); the work of industrial blacksmiths in a heavy engineering firm; and an operation involving stacking and storing paint tins and drums from a production line.

This group of heavy operations could be compared with other light and active operations in the samples. The active operations in the original heavy and active table from which operatives had been found to move before the retiring age were excluded from both groups. A comparison of the age distribution for the 23 heavy operations employing 1,240 men with that for the 20 light operations employing 853 men is shown in Table 1. There appears to be a stronger trend for men in the higher age groups to be found in the heavy operations than on the light operations. The difference between the two distributions is significant ($t = 2{\cdot}72$, $P < 0{\cdot}01$).

The operatives in this sample included only those who were employed on production and did not include ancillary workers. However, it was apparent that many of the ancillary jobs made considerable demands on muscular effort and large proportions of older people were often employed on such work. Thus in one engineering firm those engaged on heavy labouring represented only a small percentage of the total labour force, yet two-thirds of the over-70s and 43% of the 65 to 70s were employed on heavy labouring. In another firm which manufactured cars older men were often moved off the production lines to be placed in the stores department which was generally agreed to involve as much muscular exertion as any of the heaviest production operations in the factory.

Evidence concerning the employment of women on heavy work is difficult to obtain since women are not normally employed on such work. Nevertheless there were six women's operations in the sample studied which had been placed in the original heavy and active table but of these only three could be defined as falling within our present definition of heavy work. Two of the operations involved lifting up, labelling, and stacking heavy tins and containers. One of them necessitated periodically moving a tray of about a hundredweight on to a conveyor line. The third operation involved rigorous and continuous hand polishing of furniture alongside a production line. From the last operation (employing 26 women) there had been some tendency for the older women to move off on to other work. Yet five of the women employed were in the 40s and one was in the 50s. On the other two operations employing 15 and nine women, the mean ages of the older half of those employed were 50·8 and 57·2 respectively.

Evidence from the 1951 Census.—The information on the heaviness of work performed by older people given in the study above could be regarded as suggestive but no firm conclusions could be drawn because the sample could not be claimed as representative of industry as a whole. This question, however, could be pursued by detailed consideration of the larger and more representative information afforded by the 1% sample of the 1951 census. The disadvantage of such information is that the occupations listed are of necessity far more vague than in the case of a small sample where a job description can be made of each operation. A small number of occupations in the census, however, refer to work (including heavy work) which is sufficiently specific

TABLE 1

AGE DISTRIBUTION OF MEN ENGAGED IN A SAMPLE OF HEAVY AND LIGHT OPERATIONS

	Age Distribution													Total
	16–20	21–5	26–30	31–5	36–40	41–5	46–50	51–5	56–60	61–5	66–70	71–5	76–80	
Light operations	9	85	124	146	128	113	94	60	54	27	9	3	1	853
Heavy operations	2	104	149	169	163	184	177	112	74	72	22	12	—	1,240

TABLE 2

HEAVY AND LABOURING JOBS COMPARED WITH SKILLED AND LESS HEAVY JOBS IN THE SAME INDUSTRIES*

	Total No. in Sample	Percentage of Persons in Sample Falling into Each Age Group									
		15	16–19	20–24	25–34	35–44	45–54	55–59	60–64	65–69	70+
Iron and steel moulders and coremakers	625	1·3	7·2	8·3	28·5	24·6	18·9	4·6	4·0	2·1	0·48
Iron and steel foundry labourers	476	—	2·1	5·0	26·3	23·9	23·1	7·6	7·1	3·8	1·1
Bricklayers	1,519	2·1	9·9	9·2	25·4	26·5	17·3	2·8	2·7	2·8	1·4
Bricklayers' labourers	475	—	4·2	14·7	24·4	21·9	18·5	7·9	5·3	2·1	0·6
Platers	407	0·7	10·1	9·6	23·3	14·3	23·8	7·6	8·1	2·0	0·5
Platers' labourers	149	1·3	0·7	6·0	21·5	30·2	23·5	8·1	6·0	2·7	—
Plumbers	1,009	2·0	13·0	13·3	23·5	23·8	12·2	4·5	4·3	2·2	1·4
Plumbers' labourers	129	10·1	17·1	15·5	16·3	13·2	14·8	4·7	3·9	0·8	1·6
All occupied men	156,622	1·3	6·7	9·6	21·7	23·1	19·9	7·4	5·9	2·7	1·7
Dock labourers	844	0·2	1·4	5·7	16·7	23·7	27·3	11·1	6·9	4·0	3·4
Navvies	2,907	0·5	3·0	10·6	20·0	22·3	20·7	9·2	9·3	3·1	1·4
Blacksmiths	591	0·5	5·9	6·1	18·6	17·1	22·8	10·5	9·8	5·8	2·9
Handhewers and getters	1,882	—	2·8	7·2	27·4	29·3	20·5	6·4	4·4	1·01	0·7
Locomotive engine drivers and motormen	534	—	0·6	0·8	6·0	9·3	52·6	19·1	9·3	1·7	0·6
Locomotive firemen	427	—	9·1	38·6	41·7	4·9	4·7	0·7	0·2	—	—
Boiler firemen and stokers	854	—	—	3·0	14·4	23·8	31·6	11·2	10·0	3·8	2·2

* From *Census*, 1951, *England and Wales, Preliminary Report*

to enable comparisons to be made with some confidence. This is especially the case where a skilled man or tradesman is served by a labourer who performs the heavier part of the job.

The experience of the labourer sometimes enables him to be promoted to the skilled work which he has previously served. This process, however, is usually irreversible, for the skilled worker seldom returns to labouring. This is clearly a reason for expecting the proportion of persons engaged in labouring to be lower in the older age groups than in the younger. But for each trade the extent of this will vary according to the extent to which skilled workers are recruited via apprenticeships or by promotion from those working as ancillary workers. However, the fact that there is some promotion from the ranks of the unskilled will tend to reduce the numbers which we would otherwise expect to find in the higher age groups.

The method which we shall employ in this section is to compare all recognizably heavy occupations and labouring jobs with the skilled and less heavy occupations in the same industry.

The first comparison which can be drawn is for foundry workers, between iron and steel moulders and coremakers and iron and steel foundry labourers (Table 2). The percentage of labourers in the 45–54 age group and in each successive age group is higher than the percentage of skilled workers. The same trend is apparent when a comparison is made between bricklayers and bricklayers' labourers. From the 45–54 age a higher percentage of labourers is shown than of skilled workers. In the 55–59 age group the difference is pronounced and is also marked in the 60–64 age group. However, in the 65–69 and 70+ age groups there is some indication of a reversal of these trends. In the case of platers and platers' labourers no marked difference of trends in higher age groups is at first apparent. The 45–54 age group shows virtually the same percentage. The percentage of labourers in the 55–59 age group is slightly higher than the percentage of skilled workers but after 60 there is some indication of a reversal of the trend. The same reversal of trends may be observed with regard to plumbers and plumbers' labourers. The percentage of plumbers' labourers is slightly higher for the 45–54 and 55–60 age groups but thereafter the trend is reversed although the differences are not significant. Plumbing is a good example of an occupation in which persons become tradesmen via labouring; many of the younger plumbers' labourers are in fact apprentices learning the trade. Thus there is a high proportion of plumbers' labourers among the under-20s. Yet in spite of the drift of plumbers' labourers into plumbing the percentage of plumbers' labourers in the higher age groups is not markedly diminished.

A number of other heavy occupations are recognizable from the census. These are dock labourers, navvies, blacksmiths, and handhewers and getters shown in Table 2. All four occupations show higher percentages in the 45–54 age group than for all occupied men. The dock labourers, navvies, and blacksmiths show high percentages of persons in each of the higher age groups, excepting only the 70+ age group in the case of the navvies. The handhewers and getters, whose occupation at the coal face must be reckoned as one of the most arduous industrial operations, show slightly lower percentages than for all occupied men from the age of 55.

The youngest age distribution of any heavy operation undoubtedly belongs to locomotive firemen. One notes the marked difference between

the age distribution for locomotive firemen and for that of the skilled workers whom they assist, *i.e.*, locomotive engine drivers. The reason for this is simply that locomotive firemen are usually promoted from this grade of work and normally to engine driving by the age of 40. This is the extreme case of an unskilled occupation serving as an apprenticeship for the skilled job. It is interesting to note, however, that an occupation comparable in many respects with that of locomotive firemen but one from which there is no recognized channel of promotion, *i.e.*, that of boiler firemen and stokers, shows a relatively older age distribution, although after the age of 65 there is a sharp decline.

In summary of this section then it would appear, when comparison is made between skilled and unskilled jobs within the same occupation group, that in spite of the tendency for promotion to reduce the numbers of persons in the higher age groups, fairly large numbers of older persons still tend to be employed on ancillary and service operations. Heavy labouring, together with a number of other recognizably heavy occupations, contains relatively high proportions of persons in the higher age groups especially between the ages of 45 and 60. There is, however, some indication of a reversal of this trend after the customary age of retirement, 65, when persons engaged on the more skilled trades appear to hold a firmer grip on their jobs than do persons engaged on heavy unskilled work.

Before finally passing from this section it seems worth referring to an indication of comparable trends in the United States. The Committee on Aging and Geriatrics (1952) gives information on the major occupation groups of employed persons by age for the month of January, 1952. While heavy work is not mentioned as such, the results are revealing if we bear in mind that most heavy work in industry is usually covered by labouring and service operations. Below the age of 45 operative and kindred persons form 21% of employed persons while service workers (excepting those in private households) form 8%. But while the percentage of operatives employed in the age groups 45–54, 55–64, and 65 and over shows a decline with figures of 19%, 17%, and 10%, the service workers show an increase with age with figures of 8%, 10%, and 13% respectively.

The Allocation of Heavy Work in One Factory

Heavy operations in industry are often those which have been long established. Newer operations tend to be more highly mechanized and therefore usually involve little physical exertion. It may be largely for this reason that older operatives are employed on the heavy (*i.e.*, long established) operations while younger labour is placed on operations which are newer and lighter. This is likely to occur where the mobility of labour within a firm is low.

An opportunity to consider the relationship between age and heavy work where internal labour mobility in a factory is high was afforded by a firm which manufactured batteries. In order to minimize any possible risk of lead poisoning operatives were periodically switched from one department to another and from job to job. There were four departments whose operatives were interchangeable and in each of the departments there was a considerable amount of heavy work.

A Hollerith card was provided in the firm for every job carried out during each day or part of a day. The information on the card included the date, the clock number of the operative, the job, clocked hours, and earned hours. It was thus possible to obtain a detailed record of the jobs held by each worker throughout the year. Over 100,000 job cards were analysed for 327 men employed on 34 operations.

Before the final results were worked out the author asked the time study department (which was responsible for fixing the fatigue allowances for the operations) to place the operations into five grades according to the degree of physical exertion required. Grade I indicated very heavy work, Grade II heavy work, Grade III moderately heavy work, Grade IV moderately light work, and Grade V light work.

The records could be handled in a number of ways. The most straightforward analysis could be carried out by counting the number of job cards falling into each grade for each of the age groups. The percentage of work done by older workers on this criterion is shown for each grade in Table 3.

TABLE 3
PERCENTAGE OF WORK DONE BY OLDER WORKERS ACCORDING TO DEGREE OF PHYSICAL EXERTION REQUIRED

	I	II	III	IV	V
No. of operations in each grade	4	4	11	12	3
No. of persons who worked in each grade	35	63	283	312	90
Percentage of work done by under 50s	35·8	81·7	71·1	73·5	89·5
Percentage of work done by age group 50–54	23·5	14·2	17·7	13·8	10·5
Percentage of work done by age group 55–59	23·4	3·9	9·1	7·5	0
Percentage of work done by age group 60+	17·3	0·2	2·1	5·2	0

I = very heavy. V = light.

It will be seen that the heaviest operations showed the highest proportion of work done by older

persons. The lightest operations showed the smallest proportion of work done by older workers.

In the above classification the number of job cards was clearly a far less exact indication of the amount of work done than the amount of time spent on each job. One of the reasons for this was that some operations tended to carry with them a larger number of job cards than others. While the time spent on each job was recorded on the job cards the information had not been separately extracted during the automatic computation for reasons of financial economy. The sheets contained information on jobs in chronological order and to have obtained information on the total time spent on the various jobs would have meant that all the cards would have had to be analysed twice. It was possible, however, to find out the actual time spent on the various jobs for a small group. Accordingly all those in the age range 55–65 were compared with a sample of equal size in the 25–35 age range in respect of the number of hours spent on the different grades of work (Table 4).

TABLE 4

HOURS SPENT ON WORK GRADED ACCORDING TO PHYSICAL EXERTION (TO NEAREST HOUR)

No. in Sample	Age Group	I	II	III	IV	V
22	55–65	2,311	2,312	16,707	14,436	0
22	25–35	73	5,572	17,917	13,203	503

It will be seen that the greatest differences between the two groups occur in the extreme grades, the overwhelming proportion of the very heavy work being done by the older people and all the very light work being done by the younger people.

It may be seen from Tables 3 and 4 that while notable differences showed themselves between the age groups in the two extreme grades most of the work carried out fell into grades III and IV. The operations in these two grades included both production and non-production jobs. The existence of a large number of non-production jobs reflected the fact that production workers were often taken off their own jobs and placed on to unskilled work. This was because fluctuations in demand, linked especially with seasonal factors, affected the manufacture of the product concerned to a considerable extent. When the data presented in Grades III and IV of Table 4 were analysed in terms of production and non-production jobs (Table 5) it became clear

TABLE 5

JOBS IN GRADES III AND IV (FROM TABLE 4) SUBDIVIDED ACCORDING TO PRODUCTION AND NON-PRODUCTION JOBS

Age Group	III (Hours Worked)			IV (Hours Worked)		
	Total	Production	Non-production	Total	Production	Non-production
55–65	16,707	9,104	7,603	14,436	11,613	2,823
25–35	17,857	17,018	839	13,203	13,013	190

that the older people were given a considerably larger share of the non-production jobs than the younger ones. In other words it would seem that younger workers had "first preference". This might explain why some of the heaviest work was carried out by older people since it was work that younger people would be less willing to undertake. This is not to say that older workers were on heavier and unskilled work because they had never had an opportunity to engage on other types of work, for all people in the three departments concerned were supposed to move periodically between jobs. In order to ascertain how far this was true a check was made on the total number of jobs held by all people during a year. The results of the analysis are shown in Table 6. It will be seen that not all operators changed their jobs during the period of observation, but the chief point of interest is that the older people changed their jobs at least as frequently as younger people. Indeed there is a significant tendency for internal job transfer to increase with age. This is of considerable interest in view of the fact that the tendency for external labour turnover to decrease with age is marked and has been well authenticated (Kitson, 1925; Miles

TABLE 6

THE RELATIONSHIP BETWEEN AGE AND INTERNAL JOB TRANSFER: NO. OF JOBS HELD BY 327 MEN IN THREE DEPARTMENTS OF FACTORY DURING A YEAR

Age Group	Mean No. of Jobs Held per Age Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14
60s	7·00	—	1	—	—	—	—	4	—	—	—	—	1	—	—
50s	6·24	3	5	7	2	7	7	4	0	4	4	2	0	3	2
40s	4·97	10	6	8	9	9	11	6	5	3	2	1	1	1	—
30s	3·53	46	14	15	9	16	7	10	4	4	2	1	—	—	1
20s	3·46	18	12	6	16	6	2	6	2	2	—	—	—	—	—

There is a significant correlation between age and job transfer ($r = 0{\cdot}288$, $P < 0{\cdot}001$)

1935; Schonfield, 1950; Long, 1951; Wallace, 1951; Jefferys, 1954). That the reverse trend exists within a firm may be due to the greater experience of the older workers and therefore the greater readiness of the management to place them on to a wider range of jobs according to the dictates of circumstance. However, this is a matter that must be pursued elsewhere. The relevance of the data for our present problem is that they illustrate that older people were not employed on heavier jobs because they suffered greater restriction of opportunity from working on other types of job: rather it can be concluded that while they worked for some time on the less heavy operations and the production jobs of Grades III and IV they would hold such jobs for relatively short periods and incline more towards the heavy and the non-production operations.

Discussion

The evidence presented in the review and study above makes it plain that it is not uncommon for the heavy jobs in industry to be carried out by older workers. In a previous paper the author (1953) has presented information concerning the type of operations from which older people tend to move before the age of retirement. Operations which gave evidence of such moves were relatively few and the number of older persons affected, other than those suffering ill-health, appeared to be small. Such information would appear to be in line with the evidence presented in this paper which has shown some tendency for older persons to be engaged on those jobs in industry which make demands on physical exertion. However, the evidence cannot be regarded as unequivocal. Richardson (1953), in an important study in this field, gave evidence to indicate that moves of older persons from heavy to lighter work were common. His general conclusion that "the real trend of transference to lighter work is a low incidence until the 40s and a rapid rise from then on" does not appear to match the evidence presented in this study. The reasons for this apparent discrepancy must be considered.

Two explanations may be suggested.

(1) The different criteria adopted by the writer and Richardson may be responsible for the general difference in the results and conclusions. For example, moves where ill-health was a factor in the change were excluded from the writer's sample but included in Richardson's sample. As it is well known that health tends to decline with age this might account for the different trends noted.

Different criteria may also have proved of importance with regard to the "heaviness" of the operations considered in the two studies. Heaviness has not been adequately defined in industrial studies of ageing, for example, in terms of the oxygen requirements associated with various forms of work. Comparison therefore of the results obtained by Richardson with those obtained by other workers may prove difficult since no criteria for comparison exist. It is thus possible that the operations considered by Richardson in the coal-mine and foundries were more arduous than the "heavy" operations studied in other investigations and the tendency for older workers to move away from these operations might therefore be the greater.

(2) An alternative interpretation may be proposed for the results that Richardson presents. It may be noted that conclusions reached depend on the replies to certain questions. The persons interviewed, aged between 50 and 79, were asked about their work history, whether they had ever moved from heavy to light work, and if so at what age the move occurred. The rates of transfer per year were based on what the older people remembered about their jobs when younger. Thus the rates of transfer for the 20s were calculated from the replies of those in the 50s and over. There are grounds here for believing that forgetting about a change that had occurred 30 years earlier might account for the very low figures extrapolated for the younger age groups. This hypothesis may be followed up by examination of the data in Fig. 1 of Richardson's paper. The rate of transfer per year appears to be approximately twice as great when calculated on the basis of the replies of persons interviewed for whom that age group was the preceding age period as when the rate of transfer is calculated from the replies of those who are older than the age group in question by more than one age period. For example, for the 50–54 age group the rate of transfer per year as reckoned from the replies of those aged 55–59 is 0·0512 but as reckoned from the replies of those aged 60–64 the figure is 0·0202. If we may suppose that a person interviewed is more likely to recall correctly a change to lighter work that was made in the last age period over one that was made more remotely in the past, re-examination of the data on this basis becomes desirable. Thus when rates of transfer are considered for the age period preceding age of interview the following Table* may be drawn up:

Age Group	Rate of Transfer per Year
40–49	0·0296
50–54	0·0512
55–59	0·0676
60–64	0·0790
65–69	0·0666

* Extracted from Richardson's paper, Appendix, Tables A and B.

The only notable feature of the Table appears to be the sharp rise in the rate of transfer between the 40s and the early 50s. In all probability, however, this is to some extent an artefact as the figure given for the 40s is for a 10-year period and based on the replies of those who are removed from the possible age of transfer by a span of from one to 14 years whereas for the other age groups, which cover five-year periods, the span is from one to nine years. On our present hypothesis this should have the effect of reducing the incidence of those who recalled changing to light work in their 40s. Thus we are left with a rise of from 0·0512 in the early 50s to 0·0666 in the late 60s.

Our conclusion concerning Richardson's data is that there seems no real evidence to indicate a move away from heavy work at least before the 50s. But there is some evidence in the two foundries and coal-mine studied of a tendency to move on to lighter work in the 50s and 60s. In the two foundries the tendency for older workers to be engaged on the lighter work is slight but not significant, but in the coal-mine the association is significant at the 5% level. It is important, however, to bear in mind what the term light or lighter work covered. Richardson states :

> " Indeed the most important component of ' light ' or ' lighter ' work, as these terms were used by the men interviewed, was his opportunity to control the pace of work and the distribution of rest pauses . . . it is important to emphasize that men often moved to lighter work yet still remained in the moderate category or even (in a few cases) in the heavy category. Provided the effort was broken up by rest pauses, the intensity of effort seemed of secondary importance. . ."

The replies of those interviewed as to the features of work which caused difficulty also indicate that heaviness was not of sole or prime importance. Richardson states that the outstanding reply given was about the effects of speed. Even in the case of very heavy work it was not the heaviness of work as such that was to the fore. Thus the older miners complained of shortness of breath in getting to the coal face and keeping up with the younger men but once at the coal face worked without visible distress and the remark repeatedly made was: " At my job I'm all right ".

This internal evidence is in line with evidence previously produced by the writer (1953). In a study of operations from which older people tended to move before the age of retirement the work was generally referred to as heavy in the factories concerned. But most of the operations did not in fact involve heaviness in the normally accepted use of the term, *i.e.*, in the sense of work requiring concentrated effort as in lifting, pushing, pulling, and so on, but rather the work involved more typically active movement the pace of which was determined externally, *i.e.*, by the demands of a team, machine, or conveyor. Thus " heavy " was used in a functional rather than a descriptive sense. Similarly in the case of the " light " work to which older people moved the demands of the job often did not appear to be light at all for they frequently required lifting and other forms of concentrated effort.

While there is some tendency for older workers to move from certain types of heavy work, it is nonethe-less apparent that there is a tendency for older workers to be found on many operations requiring physical effort. Richardson points out, however, that the absolute numbers of persons involved on heavy work at the upper end of the age scale is often small. This applied also to the data for the battery factory considered in Table 6. Richardson concludes that the small numbers in the higher age groups reflect changes by older people to lighter work.

It is clear that such a tendency exists but its interpretation seems open to doubt. While it could indicate a general tendency for older people to move towards lighter operations on account of declining capacity to work, it might also indicate no more than that the amount of heavy work in industry is declining. While both processes may operate to some extent, the former process has perhaps been over-emphasized at the expense of the latter as may be indicated by the evidence from the studies of age distribution on heavy and light work. These show not only that the numbers of older persons employed on heavy work are small but that the numbers of younger persons so employed are small also. Moreover such studies do not bear out the theory that older people gravitate towards lighter production operations since they seldom appear to be present in large numbers on such work.

The case of the battery factory considered earlier also does not support the notion that older people on heavy jobs gravitate towards the lighter operations. There was ample light work in the departments studied to which older workers might have moved. The rate of internal job transfer in these departments was high (being carried out in the interests of health) and older workers actually moved from job to job more frequently than younger persons. Yet the pattern of the very heavy work tending to be carried out by older people and the very light work by younger people still held good. The most likely interpretation is that the older people tended to work more on the heavy than light operations because younger

workers were preferred for the latter. The ability to cope with machine work and the ability to act with the necessary speed of reaction—abilities closely associated with light work—were said to be more in evidence amongst the younger people.

Where older people have difficulty in maintaining their performance it would seem then that in general they do not move on to the lighter operations for which there is in fact more competition, but rather they move away from production work. They move, therefore, into ancillary jobs and become gatekeepers, night watchmen, and so on, or they move on to labouring jobs which tend to be heavy but where they can work at their own speed.

It seems likely then that there is some tendency in industry for older people to incline towards heavy work. In a previous paper the writer (1953) has shown that older workers transferred from active production line operations tended to be placed on heavy labouring jobs or work in the stores involving manual handling of heavy parts. More specific evidence on this subject has come from Barkin (1933). In an analysis of the jobs on to which newly hired workers were placed Barkin found that it was on the operations requiring greatest physical exertion that the newly hired older workers had the greatest hold.

That older people should be engaged on or deliberately placed on to heavy work does not of course infer any suitability either in terms of capacity or preference. Indeed, in the study of Thomas and Osborne (1950) 69% of the older people interviewed, *i.e.*, those between the age of 55 and 74, employed on very heavy labouring, found their work a strain—almost twice as high a percentage as on the types of work involving less physical labour.

Nor does the fact that older workers are placed on work making demands on effort rather than speed necessarily mean that the decline in physical strength with age is less than the decline in speed of movement. Indeed some of the evidence indicates otherwise. For example, the decline in pull or strength of grip seems relatively greater with age than the decline in speed of blow, in reaction time, or in speed of movement (see Ruger and Stoessiger, 1927; Fisher and Birren, 1947). But this difference in terms of maximum performance does not necessarily translate itself into a difference in achievement in the industrial situation. In semi-skilled operations where demands are made largely on speed of performance (once the initial skill has been acquired) decline in speed may bring about a decline in output of a corresponding order. On unskilled operations, on the other hand, where the main demand is on effort, loss of strength will not necessarily show itself as any obvious disadvantage, for maximum strength is seldom, if ever, demanded. Rather it may only mean that older people experience greater strain in coping with a given work schedule than younger people. But this they are prepared to do for it is only by dint of such effort that older workers are able to maintain their security of employment.

Finally a few words may be said about the practical implications of the theme presented. It will be seen that the proposal to make work lighter in order to help older workers might not have this effect at all. A lighter operation is likely to be one on which the emphasis will change demands from effort to speed, and the capacity of older workers to carry out the task efficiently relative to the capacity of younger workers may well be lower.

The effects which the growing introduction of lighter work will have on the employment of older workers will depend on circumstances—on the attitude of management (*i.e.*, whether management is willing to cushion older workers), on such governmental measures as may encourage firms to employ older persons, and finally on the supply and demand of labour. If sufficient younger labour is available the increase in the amount of light work might tend to increase the employment difficulties of older people. But if labour is scarce older people may stand to gain in that they may be able to continue longer in work through the reduction in the amount of effort that the work involves without their hold on the work being reduced by younger competitors.

Where the effort is taken out of skilled work the older worker is likely to derive the greatest advantage, for if the older worker's hold on the job depends on his skill rather than his capacity for effort or speed, the elimination of the " heaviness " from an operation will not impair his competitiveness *vis-à-vis* younger workers but rather it will improve it by eliminating that aspect of the work in which he is inferior.

It would appear then that the possession of skill offers the worker a surer opportunity of employment in later life than does the prospect of lighter work. At present it is clear that high percentages of workers reaching middle and late maturity possess no recognized skill and have little chance of entering into skilled work owing to the barriers against training and apprenticeship which exist in respect of age. There are grounds therefore for believing that the most progressive and far-reaching approach to this problem would rest with new plans and policies for training and retraining workers before they

become old. It is a matter for research and for industrial experimentation to show if and how this project can be undertaken successfully.

Summary

An investigation into the age distribution of persons employed on heavy work in industry is described. In a sample of operations studied, the tendency was found for a larger proportion of persons in the late 40s, the 50s, and the 60s to be engaged on heavy work than on light operations. Similar findings appeared from an analysis of occupations and jobs listed in the 1951 census. Those occupations which could be recognized as heavy and strenuous tended to have a higher proportion of persons engaged on them between the ages of 45 and 60 than did lighter skilled operations in the same industries.

An opportunity of studying job changes of different age groups as between light and heavy work was provided by a large factory in which frequent job changes were carried out in order to minimize any possible risk of lead poisoning. Although most workers carried out a number of varied jobs during the year which involved experience of both light and heavy work, the heaviest work tended to be carried out by the older workers and the lightest by the younger workers. In the intermediate grades there was a tendency for older workers to be engaged predominantly on the non-production jobs.

The findings suggest some difficulty in the application of the commonly accepted formula that older people should be given light work. On light production work it appears that older people face serious competition *vis-à-vis* younger workers, while on non-production work, consisting typically of labouring and other heavy manual jobs, it is easy for them to find employment. Improvement in the level of skill of older workers would appear to offer more promising hope of employment in later life than would the increased provision of light work, and the need for the development of facilities for training and retraining older workers is emphasized.

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DERMATITIS FROM SOLUTIONS OF SODIUM AND CALCIUM CHLORIDE IN THE COAL-MINING INDUSTRY

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The harmful effects of salt on the skin were first described by Paracelsus (1493–1541, see Schwartz, Tulipan, and Peck, 1947), and there have been accounts since confirming this clinical observation in many industries. Ulcers of the legs occur in salt-miners (Ramazzini, 1700). Salt-water boils are found in shipwrecked sailors and deep-sea fishermen (Critchley, 1943); dock labourers carrying bags of salt develop ulcers of the shoulders, and women in brine bath establishments get slight dermatitis (White, 1934). Fresh herring carriers and picklers develop boils and a pyogenic dermatitis on the inner aspect of the forearm (Collis, 1913) and deep, painful ulcers on the knuckles and alongside the nails. In salt factories perforation of the nasal septum and a dry eczema of the skin are described (Schwartz and others, 1947).

Concise accounts of brine dermatitis in the coal-mining industry are rare although the chlorides of natural pit water have been blamed for skin rashes (Fisher, 1944). White (1916) describes an acute eczema of the right hand in a miner which he attributes to the high chloride content of the explosives in constant contact with the skin.

This paper describes an outbreak of industrial dermatitis due to brine during the sinking of a pit shaft, and also contains observations on skin reactions due to a similar cause made over the past three years at another colliery which is in full production.

Environment of Sinkers of a New Shaft

A major problem in shaft work is the ingress of water, and there are several ways of dealing with it.

This particular shaft was to be sunk through a well known water-bearing stratum, the Bunter Sandstone Bed, and in order to prevent flooding an artificial ice wall was created around the site to a depth of 750 ft. Holes were bored peripherally around the shaft area and large pipes inserted; brine at a very low temperature (14° F.) was circulated, freezing the soil and water to a range of 6 ft. The shaft was then dug in the middle of this area. It is usual to assist the manual excavation by blasting, which requires boreholes sunk to a depth of 7 ft. The frozen chippings released by the drill bit tend to refreeze at once and are difficult to evacuate. Compressed air is driven down the centre of the boring bit of the drill to blow them out, and brine, which has a low freezing point, is poured alongside the drill to keep the chippings from refreezing. The holes are filled with brine which is blown out by compressed air jets immediately before inserting the explosive, and the displaced brine liberally sprays the borers. Although 30 men work each shift in the shaft, only 10 of the more experienced bore. The boring shift occurs only irregularly as the shaft walls need consolidation every 100 ft.; thus about 30 men were at risk. Three trained shaft men were employed on the surface to replace absentees among the sinkers; it is uneconomic to employ more, but this number proved inadequate to cope with increasing incapacity due to dermatitis. The problem was, therefore, acute from its industrial aspect.

Clinical Features of the Shaft-sinking Outbreak

Eighteen men reported for treatment to the Medical Centre and on several occasions all the men boring were inspected in the pithead baths after the shift. There appeared a fairly constant clinical picture which was similar to that described by Collis in the herring picklers. It consisted of (1) punched-out ulcers of the knuckles; (2) a follicular excoriated dermatitis with well marked erythema on the flexor aspect of the forearm, and a smaller localized area over the humeral origin of the forearm extensors; (3) boils on the flexor surface of the wrist and occasionally on the neck; (4) three cases showed an excoriated dermatitis of the front of the ankles and shins.

It was considered that the brine (an 8% solution of calcium chloride) was the cause of the trouble, and this was explained to the men. Jaconet sleeves were

quickly made and it was significant that the borers wore them regularly and eagerly renewed them when they wore through or were torn. Brine was used sparingly and all skin irritation received early attention. The affected part was scrupulously cleaned and zinc and castor oil cream applied by the first-aid attendant who was available actually at the baths at the end of each shift. The trouble subsided quickly with these measures.

Outbreak of Dermatitis at a Large Colliery

Coal-miners, however, who work on the coal face in pants, vest, stockings, and boots at higher temperatures are often exposed to brine solution and complain of skin irritation. During an investigation prompted by such an occasion, observations were made at a wet face at another colliery in full production over a period of three years. Water was constantly on the floor and intermittently ran from the roof as faults were struck. Analysis of the water showed it to contain :—

$CaCl_2$	51,900	parts per million
MgCl	10,200	
NaCl	129,500	

The coal seam worked was 4 ft. 6 in. thick and conditions, apart from the water, were uniformly good and constant. From October 15 to November 14, 1951, hygrometer readings and ventilation speeds were taken daily. The air entered this coal face at a speed of 171·2 ft. per second at a dry-bulb temperature of 78·7° F. and a relative humidity of 52·5° F. After passing along the face the relative humidity of the air rose to 65·1 while the dry-bulb temperature was 79·1° F.

Approximately the same 100 men worked on this face, of whom 12 were certified as suffering from industrial dermatitis by surgeons of the Ministry of Pensions and National Insurance during the three years. This figure is significant as during the same three years only 24 other cases were certified from this colliery, which has a population of 1,750 men working, of whom approximately 650 are coal-face workers. The distribution of the initial attack of dermatitis in these 12 was on the lower legs, but not extending to the feet and toes (five cases), the inner aspect of the inner forearms but not hands (three cases), shoulders extending along the outer aspect of the upper arm (three cases), and buttocks (one case).

Discussion

The response to the measures adopted in the shaft sinkers suggested that the calcium chloride was the cause of the trouble. An attempt was made to assess the local irritant effect of the same solution. A gauze pad soaked in the solution was bandaged just above the elbow of seven volunteers from a colliery office. The pad was kept in position for seven days and soaked in the solution each morning. Two complained of itching in the elbow flexure and one developed an erythematous patch studded with a few vesicles. A patch of erythema appeared on the elbow of another patient, but none complained of the skin beneath the pad. The other factor involved was probably friction, although White (1934) and most authorities suggest that crystals must be added to sodium chloride to produce any skin lesions. Nash (1955) describes a coagulative necrosis of the skin of the friction areas of the knees due to a 40% solution of calcium chloride in a Turkish labourer after one exposure. The lesions in Heppleston's case (1946) were present where the edges of gum boots rubbed the skin of the knees. Friction would explain the distribution of the lesions in the outbreaks described in this paper. The other interesting feature is that the sinkers worked fully clothed at a temperature of 32° to 36° F. while the coal-miners worked dressed only in boots, socks, pants, and vest at a much higher temperature.

Summary

An outbreak of industrial dermatitis due to brine (calcium chloride) is described in sinkers, and an account given of industrial dermatitis due to solutions containing chlorides at another large colliery. The importance of the harmful effects of chlorides is emphasized in view of their increasing use underground to allay the dust.

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MISCELLANEA

Four Studies of the Relation between Psychological and Occupational Handicap among Industrial Workers

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In the last of the famous series of reports issued by the Industrial Health Research Board it was made clear that the valuable and interesting survey carried out by Russell Fraser and his colleagues (Fraser, 1947) was essentially psychiatric, as distinct from psychological, in approach and technique. When the Medical Research Council shortly afterwards decided to form the present Unit, provision was made from the outset ensuring that in the more intensive industrial surveys likely to occupy a section of the Unit for several years one or more psychologists would have an active part. The present paper reports the general outcome of that decision in a manner which it is hoped will prove sufficiently non-technical to interest a wide audience. (The reader desiring more detailed information about the methods used is accordingly referred to a number of scientific papers quoted which contain full supporting evidence for the findings reported here.)

The studies to be described had a single objective : to demonstrate the extent, if any, to which psychological handicaps, such as inadequate general intelligence or emotional instability, are connected systematically with occupational handicap among industrial workers. Each study contributed to the design of the next, and together they represent an integrated programme of field research and related statistical evaluation carried out during the five years 1949 to 1954 in the north-west of England.

Populations Studied

The four populations were as follows :—

(1) Eighty men between the ages of 22 and 64 years, forming the entire population of a basic production department in a medium-sized factory. These men were unskilled workers on individual piecework who had been in the department concerned for periods ranging from one to 30 years, the median falling at 10 years. This group will henceforth be referred to as " the settled workers ". (Heron, 1952a and b, 1954a).

(2) One hundred and eighty-four colliery workers between the ages of 40 and 50 years, of whom 76 spent their working time wholly underground, 25 partly underground and partly on the surface, 44 full-time on the surface as manual workers, and 39 in the colliery offices (Heron and Braithwaite, 1953).

(3) One hundred and twenty-four women between the ages of 16 and 57 years, who when seen had just become employed as unskilled workers in a wide variety of departments of a factory making electrical equipment. Reference is made opposite to two groups, described as the " older women " and the " younger women " respectively, the break occurring at 35 years (Heron, 1955b).

(4) One hundred and ninety-two men between the ages of 18 and 46 years, who without previous experience in similar work had just obtained employment as bus conductors with a large municipal undertaking (Heron, 1954b, 1955a ; Venables, 1953, 1955).

Procedures Employed

In all these studies, the task was to assess by objective means the extent of emotional instability in each subject, and, except in the case of the colliery workers, to obtain also an objective assessment of general intelligence. For this latter purpose use was made of tests of proven reliability and validity which had been found suitable for use with adults in other studies elsewhere. The assessment of emotional instability by objective means still represents a considerable technical problem, and all the procedures used were of a largely experimental kind. The results to be presented will therefore be based only upon measures which, usually in combination, justify some reasonable degree of confidence in their reliability and validity for the purpose in hand. Although for full details it is essential to consult the relevant papers (Heron, 1954a, 1955b ; Heron and Braithwaite, 1953), a few words may not be out of place here concerning these experimental measures of emotional instability. Each measure is based upon a subject's behaviour in a standardized task. The tasks range from the attempt to stand still with the eyes closed for one minute, to the very different situation involved in the completion of a health inventory. For a task of any type to be considered likely as a measure of emotional instability, evidence must be available that behaviour in it distinguishes significantly between contrasting groups of subjects who are, respectively, apparently stable emotionally and clearly unstable enough to have required hospital admission and treatment.

In each case comparisons will be made internally ; that is, the group in question will serve as its own control. This procedure avoids the very real danger of unjustified generalizations which would attend most comparisons with external standards or norms. The necessity for this precaution should a remind us of our paucity of firm knowledge in these fields of enquiry, due partly to the intrinsic difficulties of the subject matter, partly to lack of support for the necessary research.

Criteria of Occupational Adjustment

There are two complementary aspects of occupational adjustment : the satisfaction obtained by the person occupied, and the satisfaction given by him to his

employer (satisfactoriness). The establishment of suitable criteria for the measurement of these two aspects has occupied a considerable amount of time and energy during this programme. For the settled workers, two criteria of satisfactoriness were developed : one of these was a measure of individual productivity, very much more difficult to obtain than one is generally led to believe ; the other, a measure of the extent to which a man was a source of concern to his immediate superiors, when they were as far as possible considering this apart from productivity (Heron, 1952a). No criteria were sought in the colliery study, as this was made possible only as a piece of cooperative research with another team of investigators. The study of newly employed women factory workers used an arbitrary criterion of continuance in the job for a minimum period of six months ; in view of the dispersal to a very large number of departments, no other suitably general criterion could be established. In the study of newly employed and wholly inexperienced bus conductors, the six-months criterion period was again used, but this time because its end coincided with certain possibly significant changes in the status and emoluments of new conductors. For those men who continued beyond this criterion period, two fresh criteria were developed, one of job satisfaction and the other of " value to the employer ", or satisfactoriness (Heron, 1954b).

The criterion of individual productivity mentioned above was a time-study index based upon the worker's average production over a period of 67 weeks, as obtained from shop-floor records. It appeared to be so closely related to actual output (checked for 45 men over 26 weeks on a particular type of casting) as to justify considerable confidence in its use. It may be observed here that such confidence in similar indices cannot be generally assumed ; if for research purposes one must be used, it should be checked rigorously in some such manner as that described in detail in the relevant paper (Heron, 1952a).

The criterion represented by continuance in the job for a minimum period is strictly speaking a measure neither of satisfaction nor satisfactoriness, but rather a mixture of both. In so far as one can separate resignations from discharges, with confidence that the former heading does not conceal some of the latter, continuance does of course represent mainly satisfaction (provided there is something like full employment at the time). The retention of a worker for a given period can only be regarded as evidence for minimal satisfactoriness to the employer, again the level of that minimum being related to conditions affecting the firm's employment policy.

Employee satisfaction was shown in the bus conductor study (Heron, 1954b) to be composed of at least two main aspects. One is positive in nature, including such things as an intrinsic liking for the job itself—for the actual duties involved—and satisfaction with the firm as an employer. The other aspect may be described as negative, in that it is concerned with adaptation, with the acceptance of pressures : one thinks of the familiar phrase " putting up with ".

In this study the " value to the employer " of men who had stayed six months was assessed by a combination of supervisory ratings (similar to those developed for the settled factory workers) with objective data about the man's behaviour obtained from office records.

General Findings

In the study of settled workers, it was possible to state clearly that, with the effects of age and experience held constant, no systematic connexion existed between intelligence level and either productivity or the extent to which a man was a source of concern to his immediate superiors. The latter criterion did, however, show a small but significant relationship with a measure of emotional instability based on a combination of four objective tests. If to this measure another was added, representing variations in men's characteristic speed of approach to a task, the relationship with supervisory concern increased significantly (Heron, 1952b). This is probably due to the fact that the criterion of concern inevitably still included a small amount of dependence on productivity in spite of the attempt to keep it out (Heron, 1952a).

With colliery workers (aged 40 to 50) it was found that as one proceeds within the sample studied from the office stool, through manual work on the surface, to the coal face, emotional instability (as assessed by a combination of five measures) increases significantly (Heron and Braithwaite, 1953). In the absence of satisfaction and performance criteria at each of these stages, it is not possible to state to what extent man-to-man variations in emotional instability within the groups represent an occupational handicap.

Turning to the factory study of newly employed women workers, where the sole criterion was the leaving rate during the initial six months, it was necessary to exclude from further consideration 22 women who had been allocated to departments containing 100 employees or more. This was due to the fact that such departments had a significantly higher leaving rate than the smaller departments. Departments with fewer than 100 employees did not differ significantly among themselves and could therefore be considered together. This requirement reduced the total sample from 124 to 102, the new figure consisting of 49 younger women (up to 35 years of age) and 53 older women.

In the younger group, it was found that those leaving within the first six months were as a group significantly less intelligent than those who stayed. This tendency was also evident among the older women, but did not there attain significant proportions. (Another trend which did not attain significant proportions is nevertheless worth mentioning : those who left during the first six months from the younger group tended to have (as a group) somewhat more emotionally stable scores than did those who stayed. It would be of considerable interest to have further data with which to confirm or refute this observation.)

In the last study, of new entrants as omnibus conductors, it was found that those resigning within the first six months were as a group significantly less intelligent and significantly less stable emotionally than those who

carried on. A detailed examination of the data showed that these findings were caused mainly by those men who were, if the sample of 192 is considered as a whole, respectively the 10% least intelligent and 10% least stable. There was practically no overlap between these two extreme 10% groups. In each case the leaving rate during the first six months was almost exactly double that prevailing for the non-handicapped men. It was also found that the rate of discharge for dishonesty or aggressive behaviour tended to be higher among men identified by a test of experimentally induced stress as falling towards the extreme "extravert" end of the temperament continuum (Venables, 1953).

When attention is directed to those men, 144 in number, who stayed at least six months in the job, it can be reported that the dullest 11% were considered to be of significantly less value to their employers than were the non-handicapped in this respect. A significant association was also found between the category "unsatisfactory and dissatisfied" and the 20% least stable. A combined score for emotional stability, based on 12 measures, shows a systematic association with job satisfaction scores (Heron, 1955a).

One hundred and twenty-nine of these men were followed up for a further period of two years; of these 12 were discharged, leaving 117 who by the end of this extended follow-up could be classed simply as "resigned" or "still employed". The Table shows the behaviour of these men as it can be related to their categories on the negative ("putting-up with") sub-score for job satisfaction.

TABLE

RESIGNATIONS ACCORDING TO CATEGORIES OF SATISFACTION

Category	Resigned within Two Years	Stayed Two More Years	Total
A "Very satisfied" and "Satisfied"	41	42	83
B "Very dissatisfied" ..	25	9	34
	66	51	117

$\chi^2 = 5{\cdot}713$, $P < 0{\cdot}02$

The positive sub-score (active liking for the job) showed no such significant distribution. Taken together, these data therefore suggest that it is probably misleading to base predictions of employee leaving behaviour upon "global" estimates of job satisfaction; a man may like some aspect of a job very much indeed, but, as in the present instance, it may be the things he finds "hard to put up with" that determine whether he stays in it or not.

It is important to note that during this further two years no significant associations were found between emotional instability or low intelligence and leaving behaviour. From this we may conclude that so far as this particular work is concerned, such psychological handicaps make themselves felt at once if they are going to at all. It would seem that the initial stresses of adaptation, largely social in nature, are a considerable hurdle: once surmounted, the job itself can be coped with fairly successfully.

Discussion

On the methodological side this series of studies has served to demonstrate in part what is and what is not yet possible for psychology as an applied science in the field of industrial health. Relatively objective personality measures have been given what appears to be a unique opportunity to prove their worth outside the sheltered environment of university, hospital, or military establishment. Some few of these measures have survived, one (a two-part personality inventory) has been advanced to what seems a specially useful stage (Heron, 1956a and b), but many have fallen by the wayside. Criteria of individual productivity, job satisfaction, concern to the supervisor, and general satisfactoriness to the employer have been developed; in this connexion it seems essential to stress that such criteria of occupational adjustment must be "tailor-made" for each situation, certainly until much more first-class research has been done to indicate the extent to which such criteria have general validity.

There is now no justification for the widespread assumption that those on the borderlines of mental defect and neurosis are necessarily handicapped occupationally. Equally true, however, is the opposite: it cannot be assumed that such people will escape handicap in all circumstances. It is clearly unwise to quote reports based on settled workers as if these were valid for those newly employed. Young women workers without children or with children at school or nursery are clearly not comparable with older women coming out (or back) to work, possibly as an escape from the now-empty home. Generalizations are further in need of restraint when considerations about the inherent stresses and strains of particular work situations have to be brought into the reckoning. Finally, it is absolutely essential for us to realize that the extent to which psychological and occupational handicap are related is bound to be affected by the prevailing economic conditions. If what is called full employment were to become the norm, then the findings reported in this paper would have greater validity than can be claimed for them in times of economic uncertainty.

Summary

It will be apparent that these diverse findings are difficult to summarize, but some attempt should be made in the interests of clarity.

Those workers shown by test to be less intelligent than their fellows on the same factory job were not less productive.

Women less intelligent than their fellow new-entrants to factory work tended to be preponderant among early resignations, this being less marked among women over 35.

Among male new entrants as bus conductors, the 10% least intelligent were more likely to leave during th

first six months, and the least intelligent of those staying so long were considered to be less satisfactory by the employers than men of average intelligence for the group.

Emotional instability among settled male factory workers was reflected as an industrial handicap only in so far as the least stable tended to be a greater source of concern to their immediate supervisors. Productivity was unaffected except by temperamental differences in speed of approach to a task.

Among male new entrants as bus conductors, the 10% least stable emotionally were more likely to leave during the first six months, and among those staying so long the least stable expressed themselves as less able than their fellows to put up with the negative aspects of the job during the early stages.

Although the conditions of the study precluded any evaluation of the effects on occupational adjustment of differences in emotional stability among older colliery workers, evidence was obtained about differences in emotional stability among various working groups within the same colliery.

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A Method for the Determination of Carbon Monoxide in Blood

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Methods for the determination of carbon monoxide in blood based on spectroscopic analysis (Hartridge, 1922; Klendshoj, Feldstein, and Sprague, 1950) are accurate only when relatively high concentrations of carbon monoxide are present. The two most accurate methods in current use are the manometric method of Van Slyke and Salvesen (1919) and the volumetric method of Scholander and Roughton (1943). Considerable skill and practice are, however, needed to obtain accurate results. These methods have certain disadvantages in that the carbon monoxide is determined after absorption of other blood gases, and corrections have to be made for dissolved nitrogen.

The purpose of this paper is to describe a method for the determination of carbon monoxide in blood which is both simple and accurate. The procedure is similar to that used for the determination of nitrous oxide in blood described by Lawther and Bates (1953). The blood gases are extracted under vacuum after reduction of the haemoglobin by acid ferricyanide and are analysed by infra-red absorption. Other blood gases do not interfere with the estimation.

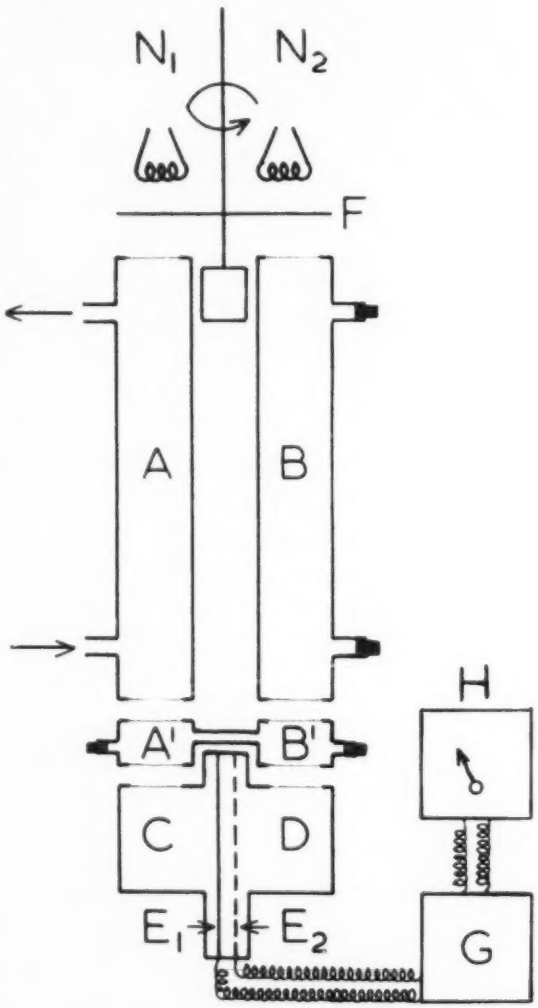
Methods

The Infra-red Analyser.—Dispersion of the infra-red spectrum is not required in this apparatus, the principles of which were first described by Pfund (1939). The analyser used is similar to that of Luft (1943) in which the portion of the spectrum that is examined is determined by a radiation detector limited in its response by being filled with a pure sample of the gas to be estimated.

Beams of infra-red radiation are emitted by two filaments N_1 and N_2 (see Fig. 1), and are transmitted through optical analyser tubes A and A^1 and identical reference tubes B and B^1 to fall on the detector chambers C and D. The latter are filled with pure carbon monoxide. A thin diaphragm E_1 separates the chambers and forms one plate of a polarized electrical condenser, the other plate E_2 being perforated and fixed. Radiation falling on the detector is selectively absorbed by the carbon monoxide and heats it, the rise in temperature raising the pressure of the gas. If a sample of gas containing carbon monoxide is admitted to A, while B contains only dry oxygen or air, the radiation falling on C will be less than that falling on D in proportion to the carbon monoxide content of the sample, and a corresponding deflexion of the diaphragm will result in response to the pressure change. The capacitance of the condenser of which the diaphragm forms one plate is thus altered.

The problem of measuring such small variations without zero drift is solved by "chopping" both beams simultaneously at low frequency by means of a revolving shutter F. The periodic changes in capacitance produces an alternating voltage output across a load resistance which is then amplified to indicate the difference in absorption in the two tubes. The gain of the amplifier can be altered so that convenient ranges are available for work with different concentrations of gas.

FIG. 1.—Infra-red analyser. N_1 and N_2, infra-red radiators; A, A^1, B, B^1, optical analyser tubes with transparent ends; C, D, detector chambers separated by E_1, a thin diaphragm, and E_2 a perforated diaphragm being plates of polarized condenser; F, a rotating shutter which "chops" the infra-red beams; G, amplifier; H, galvanometer. The arrows indicate the gas flow in A; dust filter before A not shown.



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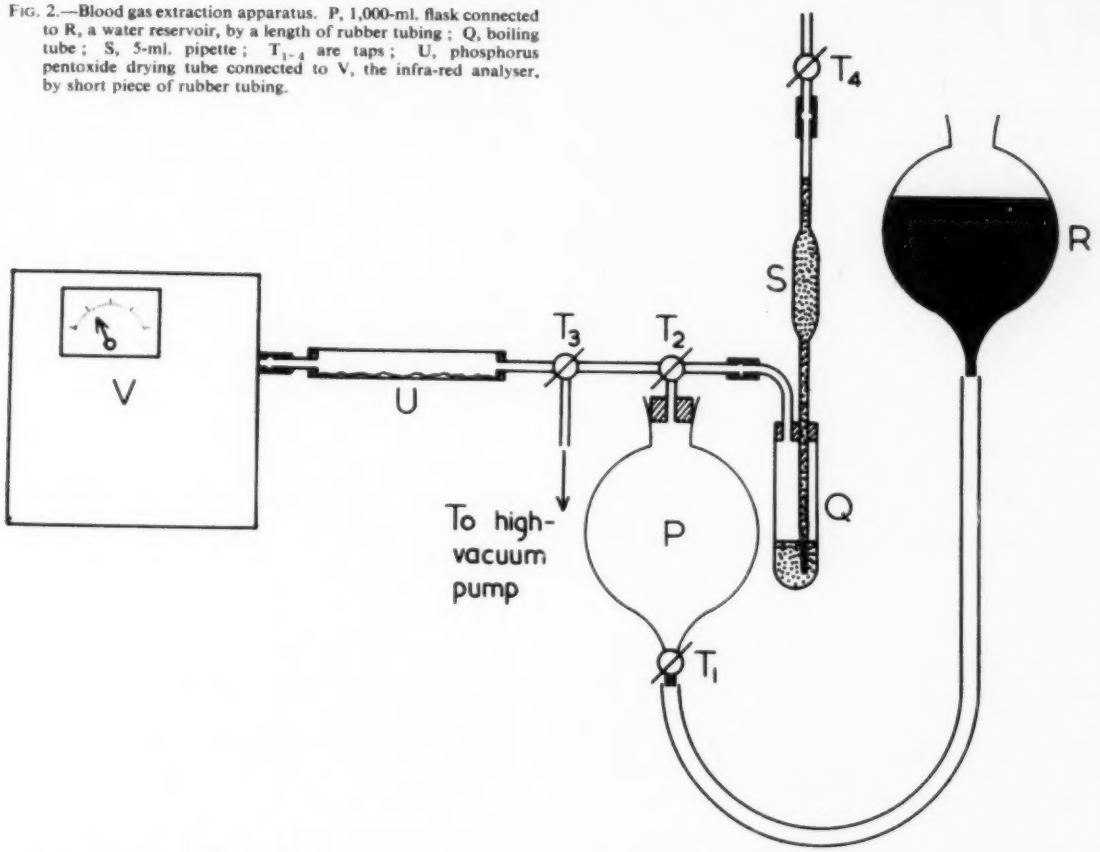


FIG. 2.—Blood gas extraction apparatus. P, 1,000-ml. flask connected to R, a water reservoir, by a length of rubber tubing; Q, boiling tube; S, 5-ml. pipette; T_{1-4} are taps; U, phosphorus pentoxide drying tube connected to V, the infra-red analyser, by short piece of rubber tubing.

The short tubes A^1 and B^1 may be used alone instead of A and B when higher concentrations of gas are being estimated. They are shown connected in Fig. 1 and are filled with dry carbon dioxide to filter off CO_2 wave bands which overlap those of carbon monoxide, thus rendering unnecessary the chemical removal of carbon dioxide from the extracted blood gases. A small dust filter is fitted before A.

Blood Gas Extraction Apparatus

P in Fig. 2 is a 1,000-ml. flask equipped with two-way tap T_1 and tight-fitting rubber bung. By means of taps T_2 and T_3 the flask can be evacuated using a high-vacuum pump. Q is a cut-down boiling tube of approximately 35 ml. capacity connected to flask P by means of a three-way tap, T_2. S is a 5-ml. pipette, the tip of which reaches the bottom of boiling tube Q, and the upper end of which is fitted with the two-way tap T_4. U is a phosphorus pentoxide drying tube 10 cm. long. R is a reservoir filled with water and connected to P by rubber tubing. V is the infra-red analyser.

Reagents

The acid-potassium ferricyanide—saponin reagent used was made up as follows :—

Solution 1

Potassium ferricyanide	25 g.
Saponin	5 g.
Water	to 100 ml.

Solution 2

Lactic acid	4·8 ml.
Water	to 100 ml.

Procedure

A stream of dry oxygen or carbon monoxide-free air is passed through the analyser and zero adjusted. A calibration mixture of 0·04% carbon monoxide in air is then passed and the analyser adjusted to read 0·04%. The analyser is then flushed through again with dry oxygen or air and the zero checked.

The pipette S (Fig. 2) is removed from the boiling tube and filled with 5 ml. of the blood under examination. Tap T_4 is then closed.

Five millilitres of Solution 1 and 5 ml. of Solution 2 are placed in the boiling tube, together with a few drops of octyl alcohol to prevent frothing. The pipette, in its bung, is firmly fixed into the boiling tube.

Flask P is connected to the high vacuum pump. When evacuation is complete tap T_3 is turned to a neutral position, and tap T_2 slowly turned to bring P and Q into communication. This results in the blood

in the pipette being drawn into the boiling tube. In the presence of the acid ferricyanide under vacuum, the blood gases are liberated.

Tap T_4 is now very gently turned and carbon-monoxide-free air is allowed to bubble through. When all bubbling has ceased (usually after about 20 minutes) tap T_2 is turned to a neutral position. Any carbon monoxide in the blood will now be in flask P.

Reservoir R is now raised, and after setting taps T_2 and T_3, the gas is displaced by water and passed through the analyser via the phosphorus pentoxide drying tube. The steady analyser reading is noted.

Calculation

Let X = analyser reading
Let Pa = atmospheric pressure in mm. Hg
Let Ta = atmospheric temperature in °absolute
Let Pw = saturated vapour pressure of water (blood) at Ta
Let V = volume of flask P in ml.
Let v = volume of blood in ml.
Then

$$\text{Volume of CO per 100 ml. blood at N.T.P.} = X \frac{V(Pa - Pw) \times 273}{v \times 760 \times Ta.}$$

Results

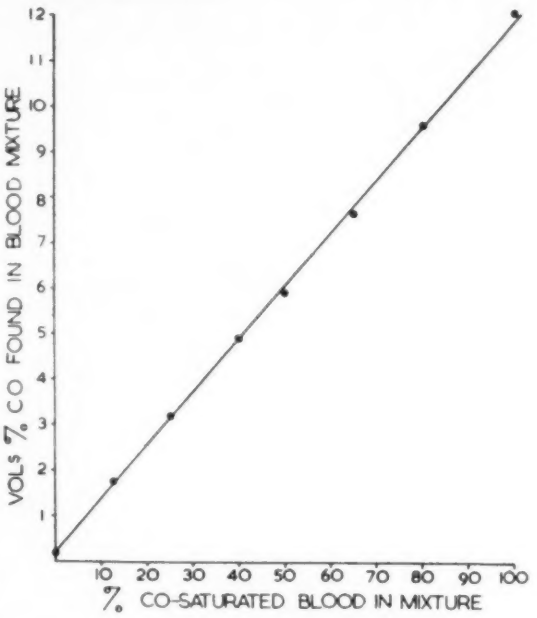
In assessing the accuracy of the method we have not used blood in which the carbon monoxide content is known absolutely since the techniques available for the preparations of such standards are subject to large errors. The validity of the method is adequately demonstrated by the linearity of the relationship between carbon monoxide found and the content of CO-saturated blood in serial dilutions.

To assess the reproducibility of the method, citrated blood was made up to contain approximately 3 ml. CO per 100 ml. blood (Sample 1) and 13 ml. CO per 100 ml. blood (Sample 2). Of these mixtures 100-ml. quantities together with 100 ml. of untreated blood (blank) were contained in reservoirs over mercury and 5-ml. samples were expelled from the reservoirs into the pipette without contact with air.

TABLE I
RESULTS OF 10 CONSECUTIVE DETERMINATIONS OF CO IN THREE SAMPLES OF BLOOD

Sample No.	Blank (ml. CO %)	Sample 1 (ml. CO %)	Sample 2 (ml. CO %)
1	0·11	2·86	13·10
2	0·09	2·85	13·10
3	0·09	2·86	13·10
4	0·09	2·88	13·18
5	0·11	2·91	13·10
6	0·11	2·88	13·18
7	0·11	2·86	13·35
8	0·09	2·91	13·10
9	0·10	2·91	13·10
10	0·10	2·88	13·18
Mean ..	0·10 ml. CO %	2·88 ml. CO %	13·15 ml. CO %
S.D. ..	0·009	0·02	0·08
Coefficient of variation ..	± 9%	± 0·7%	± 0·6%

FIG. 3.—Graph in which the carbon monoxide as determined by the method is plotted against the known percentage of carbon-monoxide-saturated blood in a mixture made up by serial dilution of fully saturated blood.



Ten consecutive determinations were made on each sample and the results are shown in Table 1. For the two lower concentrations a 420-ml. flask was substituted for the 1,000-ml. flask P.

To assess the accuracy of the method throughout its full range, 150 ml. of citrated blood was saturated with carbon monoxide in a closed vessel, and serial dilutions were made with untreated blood. The results obtained were plotted against the degree of dilution of the saturated blood. It will be seen from Fig. 3 that the relationship is linear.

Discussion

It is difficult to compare the accuracy of our method with others for want of similar statistical treatment of results. The results, however, appear to be comparable in accuracy to the manometric method of Van Slyke and Salvesen, and the volumetric method of Scholander and Roughton.

It may be of value to point out a few practical details. The dead space of the drying tube must be kept as small as possible as the air in this space together with the 200 ml. of air in the analyser tube has to be displaced before a reading is obtained. For similar reasons, flask P (Fig. 2) should be of 400 ml. or more capacity, and the gas mixture has to be run over at a moderately brisk rate to avoid diffusion in the analyser tube. Rubber connexions should be kept to a minimum as rubber absorbs carbon monoxide and releases it slowly. Calibration of the analyser immediately before each estimation is a valuable precaution, and is made easier

by placing another three-way tap just before the phosphorus pentoxide tube.

The method is accurate and requires little technical skill. An additional commendation is that the method makes use of an instrument which is frequently installed to measure carbon monoxide levels where the gas is liable to become an industrial hazard.

Summary

A method is described whereby blood carbon monoxide may be simply and accurately determined by infra-red spectroscopy after extraction under vacuum.

The standard deviation of 10 determinations at 2·88 ml. CO/100 ml. blood was 0·02, and of 10 determinations at 13·15 ml. CO/100 ml. blood was 0·08. The method was found to be linear over the range 0 to 12 ml./100 ml. blood.

We wish to acknowledge our debt to Professor Ronald V. Christie for encouragement and advice.

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The British Occupational Hygiene Society

The Assessment of Health and Disease in Industry

The fourth conference of the British Occupational Hygiene Society, which dealt with the assessment of health and disease in industry, was held at the London School of Hygiene and Tropical Medicine on April 4, 1955, the President of the Society, Dr. J. M. Rogan, occupying the chair.

The President said that although their Society was not yet three years old its record of progress seemed satisfactory. Its membership was increasing and its finances were healthy, and it was represented on the Government's Industrial Health Advisory Committee. In the years to come, however, their progress would be judged by their success in fulfilling the task laid down in its constitution—to promote the science of occupational hygiene. He was confident that they would be successful in attaining this objective, but they would succeed only if their members were active and remained so.

It was the policy of the Society to encourage young workers to give papers, so that inexperience should not deter any member from volunteering to give a contribution. Non-members could also present papers, if they were introduced by members.

Summaries of the papers read and the discussions follow.

Observations on the Assessment of Health in Industry

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It was appropriate in the first place to ask just how far the sphere of clinical medicine in industry was of major interest to the Society. The President had clarified the matter. In his view it was inappropriate to continue conferences on environmental hazards without bringing the whole subject of occupational hygiene into balance by considering also the measurement of health and disease which must go hand in hand with the environment. The basic reason for the conference was thus to examine and discuss the medical contributions that could be made in the industrial field.

The constitution and membership of the Society are an implicit recognition of the fact that the promotion and maintenance of health in industry is dependent on groups of persons rather than on any one individual or specialist. It would be foolish to think that it could depend on the medical profession acting on its own, under its own impetus, and with its traditional techniques. At the same time, industrial health is the application of medical knowledge to all employment issues affecting the well-being of the worker. And because it is concerned with the man, his work, and his working environment, it is wider in scope and more complex in its implications than curative medicine.

The potential contribution to industrial health of legislation and of employers should be more widely appreciated. Legal standards, enforced where necessary, tend to prevent firms from escaping their responsibilities. Factory legislation, for example, in controlling certain conditions of work for young persons, can be an influence on the health of this important age group possibly more powerful than that of the appointed factory doctor. Industrial managers can make possible hazards safe, and provide good working conditions. The impact of the working day, and the sum of the varying factors that go to make it up, can mould the pattern of living which a man sets for himself outside the factory.

Wide problems of clinical medicine arise in industry and assume importance, contrary to the view of some theorists who maintain that industrial health is largely a matter of engineering or statistical study. These medical problems include the examination and assessment of employees who are exposed to or are suffering from industrial disease, injury from industrial accidents, psychiatric disturbances, and also cases where there has been aggravation of disease processes by the demands of work. Many disabled workers are effective producers in the right job, so medical advice on placement can be valuable. But to be of value this advice has to be related all the time to the physical and mental demands of the work the man does.

Work study therefore is the natural corollary to clinical assessment. There is a need to develop some adequate methodology to meet the needs of doctors and other scientists and technicians working on health matters in industry. Recent investigations have shown that job analysis techniques can be modified satisfactorily for this purpose.

Assessment of health in industry could be facilitated by regional provision of suitable machinery for promoting investigations, and by the wider availability of expert advice in industrial centres—in addition to that provided by the factory inspectorate. Both these proposals could profitably be examined by the new advisory committee on industrial health recently set up by the Minister of Labour.

Discussion

Discussion centred upon the provision of ancillary services, such as radiography, dust counting, and chemical analysis. Expert advice tendered by the Factory Department and the Medical Research Council was mentioned and also the feasibility of organizing this on a more comprehensive scale, or bringing in the universities, or initiating special institutes of industrial hygiene. Extension of the work of the public analysts beyond the analysis of water and food to include the estimation of toxic substances was also suggested.

In reply, Dr. Stewart said he thought that the country could not afford to have such investigations carried out at the public expense and that industry should pay for them and would be willing to do so if proper arrangements were made. A lead should be given by the Ministry of Labour.

The Contribution of the Factory Department to the Assessment of Health and Disease in Industry

R. MURRAY

H.M. Medical Inspector of Factories

The experience of the Factory Department in assessing health and disease in industry has been long and comprehensive and it would not be possible in a short time to pay full tribute to it. This summary, therefore, is mainly confined to the part played by the appointed factory doctor and the medical inspector.

Appointed Factory Doctors

The appointed factory doctor, formerly called the examining surgeon, of whom there are some 1,800 throughout England, Scotland, and Wales, is usually a general practitioner. His main duties are as follows :—

Examination of Young Persons.—(i) All young persons starting work in any factory for the first time must be examined within 14 days to determine their fitness for employment and thereafter every year until they reach the age of 18. (ii) Boys over 16 who, in certain industries, are permitted to work at night must be examined at the start and every six months thereafter.

The appointed factory doctor may issue a certificate permitting employment unconditionally. In special circumstances he may issue a conditional certificate subject to re-examination after a specified interval or to conditions respecting the nature of the work in which the young person is to be employed. A provisional certificate lasting 21 days may be issued to enable him to obtain further medical data.

Periodic Medical Examination.—Certain codes of regulations and section 59 of the Factories Act 1937 contain provisions for periodic medical examination. A few codes require pre-employment examination. The intervals between examinations vary according to the nature of the hazard. Some of the more recent regulations provide for medical supervision in addition.

Investigation of Cases of Notifiable Industrial Disease and Gassing Accidents.—The diseases notifiable under section 66 of the 1937 Act if contracted in a factory are lead poisoning, phosphorus poisoning, manganese poisoning, arsenical poisoning, mercurial poisoning, carbon bisulphide poisoning, aniline poisoning, chronic benzene poisoning, toxic jaundice, toxic anaemia, compressed air illness, anthrax, epitheliomatous ulceration, and chrome ulceration. These must be distinguished from the prescribed diseases under the National Insurance (Industrial Injuries) Act, which now number 39 in addition to pneumoconiosis and byssinosis.

The appointed factory doctor may be asked by the Ministry of Pensions and National Insurance to give an opinion on claims for injury benefit for a prescribed disease in his district. The duties of investigating cases of notified industrial diseases and gassing accidents cannot be delegated to any doctor other than the appointed factory doctor, but the duties of examining young persons and of examining workers under various codes of regulations may be delegated, by certificate of the Chief Inspector, to the works doctor.

Medical Inspectors

The contribution of the medical inspectorate to the assessment of health and disease in industry is well recognized. The early pioneer work of Legge, Collis, Middleton, and Henry, and the work of the present medical inspectors give ample evidence of the work of this branch in the field of research.

On the more day-to-day aspect, the medical inspectorate are concerned with factory inspection, with the supervision of the work of the appointed factory doctors, the further investigation of notified diseases and the recognition and assessment of industrial hazards. They maintain a liaison with other ministries, with works medical officers, general practitioners and hospital consultants, with employers, and with trades unions.

The Need for Improved Assessment of Industrial Diseases.—The object of assessment is to provide information on which control measures can be based, and there is no doubt that the data available at present are inadequate to assess fully the true incidence of industrial disease and to recognize the part played by working conditions in the causation of disease.

Notification.—The limitations of the value of notification have been indicated by the Chief Inspector, who says in his Annual Report for 1953, in relation to epitheliomatous ulceration :

> "It is evident that the notifications received in compliance with section 66 of the Factories Act 1937 are only a partial indication of the incidence of this disease. The duties of the medical practitioner and of the employer as regards notification are of prime importance for prevention, since the application of preventive measures to new processes and their intensification in recognized hazards are the immediate sequelae."

A considerable improvement in notification is needed from the medical profession and from employers. The Annual Report of the Ministry of National Insurance indicates that among those in insurable employment there were in 1951 43,600 spells of incapacity arising from the prescribed diseases, all of which are as amenable to preventive measures as the notifiable diseases, and if fuller information regarding these were available to the Factory Department, more precise efforts could be made in their assessment and control although the task is a huge one. There is a close liaison between the Ministry of Pensions and National Insurance, the Registrar General's office, and the Factory Department concerning current industrial disease as well as mortality records.

Information about the Use and Supply of Dangerous Materials.—The Factory Inspector in the course of his work is able to note the introduction of new materials and to pass on to his medical colleagues information which can be followed up to prevent risk to health.

The Atomic Energy Authority keeps the Department up to date concerning the supply of radioactive isotopes

to industry. This kind of information is of enormous value in enabling precautions to be taken at the earliest possible moment.

Chemical and Physical Investigations.—The Engineering and Chemical Branch of the Department are able to give precise information as to the nature and composition of materials used in industry, and the Information Service has available relevant data from medical, chemical, and other technical journals.

Clinical Pathology.—There is no provision for appointed factory doctors to assess variation from normal at routine examinations by any means other than clinical examination. One of the medical inspectors carries out haematological investigations on a variety of process workers throughout the country and assists in assessing the effects of exposure, but obviously more pathological data and facilities for hospital investigations are needed. The Ministry of Agriculture and Fisheries has arranged with regional hospital board laboratories to have investigations carried out on men exposed to dinitro-o-cresol or to the organic phosphorus insecticides.

Radiology.—Radiology is a specialty in itself, and the appraisal of the radiographs of industrial workers is a difficult task demanding experience not only of radiology but of the particular occupational exposure.

Other Specialties.—Industrial medicine has need of many specialists to make a full and complete assessment of the nature and extent of industrial diseases.

Skin disease, for example, is the commonest cause among the prescribed diseases of claims for injury benefit, and the one on which expert advice is most needed, if only to reduce the risk of recurrence. The dermatologist needs to be familiar with industry and industrial processes to appreciate what and where are the risks of contracting dermatoses.

Education.—Education is the essence of the problem. The man who is sick goes to see a doctor, and it depends on how well informed the doctor is whether he can make a true assessment of the case. Doctors should be taught the elements of industrial medicine as undergraduates and the link between diagnosis and prevention should be emphasized.

The Future Contribution of the Factory Department

The setting up of the Industrial Health Advisory Committee is an indication of a fuller recognition of the needs of industrial health. Industrial health services will be developed on a voluntary basis, but as and where necessary the Minister will use his statutory powers under the Factories Acts.

With the assistance of industry the Department looks forward to the more efficient control of hazards and the promotion of health in factories, but this depends very largely on improved methods of appraisal and assessment which can only be achieved with the cooperation of all concerned.

The Clinical Assessment of Health and Disease in Industry

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Health in industry can be assessed by the pre-employment and periodic examinations. The pre-employment examination must not become an end in itself but must be related to the industry it serves. The object is to find not the superman but the man who will do the job without harm to himself or to others, and on whom the work will have no cumulative ill effect. There is a need for caution about set standards and to examine critically opinions about the employment of disabled persons such as chronic bronchitics and those who have had abdominal operations. It is not easy to assess the potential effect of work on the skin. Standards must bear some relation to the age and experience of the applicants. In the physical examination many factors are capable of accurate measurement such as the height, weight, visual acuity, urine analysis, and chest radiograph. Sexual development and literacy are checked. But heart murmurs and the anatomy of the foot cannot be assessed so objectively. It was possible only to guess at such things as reaction time and accident proneness.

Many industrial medical officers follow up the findings of the pre-employment examination, particularly in youths from 15 to 18. But the industrial medical officer must be satisfied that the reward is worth the work. A follow-up of a sample of one in ten over a period or of borderline cases might be beneficial.

Notifiable diseases are no longer such a major problem, but rather is it the new compounds which cause concern. Their production should be discussed with the doctor at an early stage so that he may assess the likely hazards. Sometimes, however, pilot production may proceed to an advanced stage and cases of unknown disease be the first intimation to the doctor of a new hazard. He may have to call a halt while he assesses the position.

Research

It is easy to slip into a routine and develop a false sense of security. Routine work need not necessarily be dull. Clear-cut objectives are necessary and the industrial medical officer should devote some time to original thought. It is important for him to see the potentialities of some chance result.

Discussion

The position of the industrial medical officer in relation to general practitioners was discussed. There might be a tendency for workers to use their general practitioners on all occasions so that the works doctor lost the opportunity of early detection of industrial hazards. The industrial medical officer had to provide an effective service, with the help of management, which would encourage his patients to come to him.

The Measurement of Health and Disease in Industry

A. BRADFORD HILL

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In England and Wales it is possible to tabulate the deaths of men according to the occupations which are recorded on the death certificates. Bringing these numbers of deaths (by age and certified cause) into relation with the numbers of men following different occupations, as recorded at the decennial census, gives, in terms of mortality, some indication and measure of special occupational hazards. The interpretation of such occupational mortality rates calls, however, for considerable caution. Thus at ages over 60 increasing numbers of men are described on the census schedules as unoccupied whereas when death is registered an occupation can usually be obtained from the informant. The rates at advanced ages are, therefore, inaccurate and attention must be mainly limited to the working ages 20–64. Occupations are likely to be accurately recorded at the census (by the man himself) and less accurately at registration of death (by the informant), and this must lead to some degree of incompatibility and to error in the death rates. Still more serious are likely to be the effects of selection affecting both entries into and exits from an occupation. Heavy physical labour, *e.g.*, foundry work, is unlikely to attract men of poor physique and health ; light jobs, *e.g.*, clerical, may well do so. Further, those who lose their health in one job may seek another and it is to the latter that their death must be debited at registration since no full occupational history is, or could be, sought at that time. Thus the coal-miner stricken with phthisis may die as a newspaper seller, the sergeant major, with rheumatic heart disease, as a cinema commissionaire. Though these selective influences to and from occupations cannot be measured, they must be continually borne in mind. They may profoundly obscure the picture sought.

Such tabulations of occupational mortality were begun by Dr. William Farr of the General Register Office in 1851 and have been issued subsequently at 10-year intervals. The object of them is to isolate, as far as possible, the specific effects of an occupation as distinct from the other factors in the environment with which the occupation may be associated—the standard of living, the housing, living in an insanitary area, and so on. To aid in this object an ingenious but simple device was incorporated in the Registrar General's Occupational Mortality Supplement for 1930–32. The mortality experience of the wives of men occupied in different ways was tabulated. Two comparisons are now available. Men occupied in a given way can be contrasted with all occupied men. The wives of men occupied in a given way can be contrasted with the wives of all occupied men. If the men in that occupation have an abnormal death rate from some cause but their wives do not, it would appear that the occupation may be responsible for the abnormality. If both the men and their wives have abnormal death rates from a cause it would appear that the living environment that they share is more likely to be at fault than the occupational environment to which only the men are exposed. Thus in 1930–32 physicians and surgeons showed a death rate above normal for digestive diseases ; their wives did not. Inn-keepers and barmen had a total death rate 50% above normal, a disadvantage that their wives succeeded in avoiding.

Though these data may not have revealed many occupational risks not already known or suspected, they do form a useful guide. Without them the relative death rates of lawyers and doctors, dock workers and carpenters, costermongers and professors, would be quite unknown. It is clear that, like all statistics routinely collected, they may well raise far more questions than they solve—for example, the relatively high death rate from coronary heart disease in the professional classes. But thereby they at least act as important leads to epidemiological inquiry and other special researches. Equally they may save a long and useless investigation by showing that there is no problem.

Death has the advantage that it is so easy to count —stone dead has no fellow. But many diseases that may be of occupational importance are not lethal. It is therefore important to consider the tabulation of statistics of sickness. A host of troubles immediately becomes apparent. How is " sickness " to be defined ? Its development and recession may be gradual, its severity can vary, and its manifestations may be related, and sometimes closely related, to subjective reactions. When is a person ill ? When are two people equally ill ? In the present issue, *i.e.*, in relation to industry, the definition will almost invariably have to be " incapacity to work ". From this it follows that recorded sickness in industry is dependent not solely upon a pathological condition but upon many other factors.

One such factor will be the nature of the employment. An attack of rheumatism that keeps the miner from the coal face will not necessarily keep the bank clerk from his desk. A simple fracture of the radius will put the bus driver out of action ; it will not stop the university professor teaching. A second factor will be the economic. Payment of wages or sick benefit during absence will have unknown effects upon the readiness with which the worker will absent himself—or can afford to absent himself—and must have unknown effects upon the duration of absence. Administrative procedures may be a third influence. Long absences may not be wholly recorded—the worker is taken off the books. Short absences of a day or two may not be recorded at all. All such matters must enter into a consideration of sickness statistics and their contrast between one industry and another, one factory and another. As with mortality rates, selective recruitment and selective discharge may be important and age and sex (and with women marital status) must be taken into account since they are known to affect rates of sickness seriously.

In view of these many difficulties of analysis and interpretation it is very doubtful whether the institution of sickness recording as a routine in all factories and

other places of occupation would adequately repay the effort and cost. On the other hand, large-scale and nationalized industries might profitably continue to collect and analyse such records. They would provide some standard experience for comparative use in smaller units where some special risk was believed to exist, and also reveal where the main problems of prevention lie, *e.g.*, in the common cold, influenza, rheumatism. The means of preventing such causes of disability should then be sought in specially designed inquiries with specially recorded data on the attacks of disease. Thus the epidemiology of the common cold may be explored by making precise observations in a selected industry. Is it, and if so, to what extent, transferred from person to person during the hours of work? If it is, to what extent can the transference rate be influenced by different rates of natural ventilation in workplaces? Can the incidence of influenza be reduced by inoculation? To answer such a question carefully designed trials will be essential. Routine sickness absence statistics are likely to be of very little value in these settings.

As regards health it may be very important to ensure the absence of specific disabilities in a man before recruiting him to a certain job. Persons who suffer from epilepsy should not become steeplejacks. But quite often disabilities are not incompatible with health. The short-sighted man may be handicapped and frequently absent " ill " if employed on fine precision work. As a small holder he may be entirely " well " and successful. A pneumonectomy may be a handicap in a professional footballer but not in a professor. The policeman may have to be " fighting fit ". Is that same fitness necessary for the pilot of a jet aircraft? The question of occupational health must often be worded as " health for what? ".

Discussion

Experiences in the coal industry analogous to those spoken of by Professor Bradford Hill were described in the discussion. The vast majority of miners with massive fibrosis of the lungs died outside the industry; another disadvantage of using death as an index of occupational hazard was the number of diseases, particularly the rheumatic ones, which did not kill.

Absenteeism was a possible index for which exact figures were available, but at present they were impossible to interpret. This matter was being investigated by the National Coal Board. It seemed probable that the only place in which health could be measured in relation to an industry was not in the industry itself, but in the associated community.

FIFTH CONFERENCE

The fifth conference of the Society will be on " The Use and Abuse of Protective Equipment " and will be held at the London School of Hygiene and Tropical Medicine on Friday, November 4, 1955.

The morning and afternoon sessions will be introduced by the Chief Inspectors of Factories and of Mines respectively, and the following papers have so far been arranged :

Protection of the Lungs, Mr. A. C. Peacock, C.D.E.E., Porton, and Mr. T. Whittaker, I.C.I. Safety Department.

Protection of the Skin, Prof. J. R. Squire, Birmingham, and Dr. A. Lloyd Potter, I.C.I. General Chemicals Division.

Protection of the Eyes, Mrs. O. R. Campbell, Birmingham, and Mr. G. V. Thom, I.C.I. Plastics Division.

Protection of the Feet, Mr. H. Bradley, B.S.A.T.R.A., and Mr. H. E. Thomas, Ford Motor Co.

Further particulars can be obtained from the Hon. Scientific Secretary of the Society, D. Turner, M.R.C. Laboratories, Holly Hill, London, N.W.3.

The Diseases of Occupations *

A Review by

RICHARD SCHILLING

Medical textbooks are nowadays seldom read for both pleasure and enlightenment. As medicine has become increasingly technical and specialized its textbooks have become more difficult to read and are used mostly for reference or during the distasteful preludes to examinations. Donald Hunter's book is an exception. It contains an abundance of knowledge, is highly entertaining in parts, and could be read with considerable interest by those who know nothing about industrial medicine. It is much more than a textbook on occupational diseases, not only because it has chapters on the Industrial Revolution, the social evils and reforms of the nineteenth and twentieth centuries, but because throughout it is flavoured with historical facts, and passages from fiction, sometimes irrelevant but always entertaining. It is an artist's impression of industrial medicine, lacking the balance and perhaps the accuracy of a textbook compiled by several authors but gaining immeasurably in its readability and therefore in its contribution to medicine because it is one man's work, painted in vivid colours and not in dull, respectable pastel shades.

There are many examples to illustrate its artistic character. A few will be mentioned. In the section on marble, a limestone harmless to the lungs as a dust, there is an illustration of Michelangelo's beautiful statue of David in Carrara marble, and an account of the Marble Arch, first built by order of George IV in the gardens of Buckingham Palace. When the Palace had to be enlarged because Queen Victoria had such a large family, it was moved to the Cumberland Gate of Hyde Park. "And then, widening of the road left it stranded in its present position amid a surge of traffic." Six pages are devoted to the development of railways in Britain and contain a descriptive passage from Dickens' *Dombey and Son* of the building of the great cutting from Camden Town to Euston in London. There are accounts of the addiction to cocaine of Halstead, one of the greatest surgeons of North America, after experimenting with it as an anaesthetic; of illiterate James Brindley building the Bridgewater Canal; and of blind John Metcalf making new roads in Yorkshire and Lancashire.

All these stories and many others have little to do with diseases of occupations and indeed may irritate the technically minded who want facts to pass examinations or help in their work. But they are fascinatingly written and a similar approach used in ward rounds and out-patients undoubtedly explains the author's great success as a clinical teacher who imparts unforgettably to students his knowledge of history, fiction, and clinical medicine.

The opening chapters give a refreshingly unfamiliar account of some of the historical and economic background of all types of work in ancient and modern times. It is not the approach of the specialist in industrial medicine who usually confines his interest to occupations in factories and mines but of the general physician who observes facts of clinical significance in every type of occupation. Who else would have considered the hazards of workers in chemical and bacteriological laboratories, of gardeners and veterinary surgeons, of the European red pepper industry, of the nomadic way of life, or of living on the Asiatic steppes?

The account of the social reforms of the nineteenth century is a series of excellent descriptions of the attempts to correct the social evils of that time. But with the chapter on the health of the worker in the twentieth century it is too disjointed and not sufficiently discursive to be a serious contribution to the history of industrial medicine; and there are some gaps which must be filled in a later edition. There is no mention of the Factories Act of 1948 and no clear picture of the appointed factory doctor who remains the backbone of factory medical supervision in Great Britain.

There is no doubt that the most valuable chapters are those on subjects best known to the author: the toxicology of the metals and their compounds, the aliphatic and aromatic carbon compounds, the noxious gases, and occupational diseases due to infections and physical agents.

The part concerning the occupational case history should be read by every medical student and doctor. One particular paragraph suffices to illustrate the importance which the author attaches to a detailed history:

> "Ask him the name of his trade, the processes employed, the tools used, and the substances handled. The name he gives to his job may be an obvious euphemism. If he tells you he's a *salvage officer* he means a *dustman*, and if he says *vermin exterminator* he means *rat catcher* . . . . Whether he be a *fish hobbler, getter-up charger, head sinker, nobbler, mucker-out, swadge sawyer, teazer, trolloper* or *whammeler*, he will respond to your detailed questions if only you are firm and tactful and show appreciation of his skill.
>
> "The name of an occupation may mislead you, for different names are used for the same or closely similar processes in different parts of Great Britain. . . . In coal-mining the shale or rock between the seams of coal is drilled or blasted by miners who may work in separate shifts from the coal-getters. The man who does this type of work is usually called a *hard-header* in South Wales, a *brancher* in Somerset, a *stoneman* in Durham, a *ripper* in Yorkshire, and a *brusher* in Kent. More than sixty names have been given to the variants of this job."

The sections already mentioned and those dealing with the pneumoconioses, occupational cancers, and diseases of the skin are well referenced, and give good accounts with plenty of illustrations of some of the best published clinical work. However, there are some surprising omissions. For example, no reference is made to Craw's work on pneumoconiosis among the haematite miners of Cumberland (Craw, 1947). There is nothing about the important recent research work on bladder tumours in rubber and dyestuff workers indi-

* The Diseases of Occupations. By Donald Hunter. (Pp. xv + 1046; 438 illustrations. £5 5s.) London: English Universities Press. 1955.

cating new carcinogens and that exposure to aniline itself does not cause bladder tumours (Association of British Chemical Manufacturers, 1953). Reference might also have been made to Hueper's comprehensive review (1953) of the occupational cancers and to the recent work on accident proneness by Adelstein (1952) and Arbous and Kerrich (1951).

There are some less important errors in an otherwise carefully written work. As some Scots know only too well, *England's* population is not 50 million persons; and Charles Turner Thackrah, a Leeds physician and one of the great pioneers in industrial medicine, died in 1833 and not in 1832.

The author has written this book primarily for students, general practitioners, and consultants. It has much to commend it to doctors in general medicine. His advice to industrial medical officers is to consult larger and more detailed books. But there is not one published in this country which deals so comprehensively with the occupational diseases as his own.

Much space is devoted to the prevention of industrial diseases by medical and engineering control which is relatively easy when the causative agent and its mode of action are known. Some of the more complex problems of occupational medicine, for example chronic chest disease, coronary artery disease, and the rheumatic disorders are only likely to be elucidated by clinical research workers using epidemiological methods. It would be uncharitable to criticize this book for its lack of reference to epidemiology since it has been written primarily for those who treat the sick, and epidemiology is not taught as part of clinical medicine in the medical schools of this country.

As a contribution to industrial medicine it is a remarkable achievement and will surely take its place among the few classics written on this subject.

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THE JULY (1955) ISSUE

The July (1955) issue contains the following papers :—

Emphysema and Proteinuria in Men Casting Copper-cadmium Alloys. By J. A. Bonnell.

Appendix : Physico-chemical Examination of the Serum and Urine Proteins in Some Cases of Cadmium Poisoning. By R. A. Kekwick.

An Environmental Study of Casting Copper-cadmium Alloys. By E. King.

Disabling Pneumoconiosis from Limestone Dust. By A. T. Doig.

An Epidemiological Study of Byssinosis Among Lancashire Cotton Workers. By R. S. F. Schilling, J. P. W. Hughes, I. Dingwall-Fordyce, and J. C. Gilson.

The Effect of Cortisone on Established Silicotic Fibrosis in the Lungs of Rats. By E. J. King, C. V. Harrison, and Daphne Attygalle.

Leptospirosis in South-East Scotland. By P. N. Edmunds.

Energy Cost of Some Industrial Operations. By D. Turner.

Cutting Oils and Squamous-cell Carcinoma. Part I : Incidence in a Plant with a Report of Six Cases. By Ernest Mastromatteo.

Cutting Oils and Squamous-cell Carcinoma. Part II : An Experimental Study of the Carcinogenicity of Two Types of Cutting Oils. By J. P. W. Gilman and S. D. Vesselinovitch.

Rheumatism in Coal-miners. Part III : Occupational Factors. By J. S. Lawrence.

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 12s. 6d.

BOOK REVIEWS

Emotions and Bodily Changes. A Survey of Literature on Psychosomatic Interrelationships, 4th ed. By Flanders Dunbar. (Pp. xxii + 1192. £6) New York : Columbia University Press ; London : Oxford University Press. 1955.

This is a remarkably comprehensive work of considerable value to those engaged in research into psychosomatic problems or whose interest cuts across the usually accepted boundaries of medicine. Some idea of its size and scope may be gained from the fact that over 4,700 references are quoted in the text, while a supplementary bibliography brings the total to over 5,000.

The layout is somewhat unusual. Each chapter is divided into two parts : the first dealing with basic problems and early work, the second with developments since 1935. This method of presentation is in accord with the policy of the author who has attempted not only to put into perspective the vast amount of research work on psychosomatic problems published to date but to show how earlier predictions have been verified with the passage of time.

The term " psychosomatic ", despite its obvious disadvantages, will, as the author states, probably persist for want of a better to call attention to the investigation and treatment of the patient as an entity, but its significance is still often misinterpreted. While there is no medical problem lacking a psychological or emotional aspect, this is frequently dismissed as trivial or a mere consequence of secondary importance. Even where emotional factors are felt to be of aetiological significance these are seldom fully explored, or, if investigated at all, poorly understood.

Many patients who suffer diseases in which, so far as causation is concerned, emotional factors appear inconspicuous or absent are paradoxically those in which investigation of this aspect may be particularly rewarding. The mechanism of conversion is not limited to hysteria and other neuroses but occurs in many diseases with organic pathology, or may be a factor producing chronicity and interfering with the success of treatment. As Deutsch says : " Conversion finds in diseased organs its most favourable sphere."

It is also clear that a physical illness may, on occasion, be a substitute for a neurosis or emotional disturbance. And, just as the neurotic, however much he would appear to wish to be rid of his symptoms, has a need for illness which may prevent recovery, so may the same be true of what appears to be a purely physically determined ailment.

It follows, therefore, that many seemingly effective medical and surgical therapeutic measures are effective only inasmuch as they relieve symptoms, while the basis of the disorder may remain untouched. This is exemplified by the well-known phenomenon of accident-proneness. Here, although the results of injury may be effectively ameliorated by the surgeon, surgical repair does nothing to lessen any increased tendency to further accidents.

Acknowledgment of this principle proves the need for reorientation. The psychosomatic approach does not merely consider the effect of mind on body, or vice versa, but attempts to avoid this dichotomy and view the diseased organism as a whole and in relation to environment.

The author claims that industrial medicine, like much of clinical medicine, has been relatively ineffective because of a lack of psychosomatic principles and stresses the need for close cooperation between the factory doctor and those in charge of personnel. Because emotional disturbances arising out of economic, social, and industrial situations may be precursors of both mental and physical illness they too need full consideration in the prevention of industrial disability.

Apart from its obvious value as a work of reference this book formulates a basic discipline necessary for both general practitioner and specialist. Whether or not all the material is acceptable, there is provided a potentially fruitful method of approach to many medical problems hitherto considered insoluble or obscure.

W. H. TRETHOWAN

Measurement of Morbidity. General Register Office : Studies on Medical and Population Subjects, No. 8. (1*s.* 6*d.*) London : H.M. Stationery Office. 1952.

This is a report of the Statistics Sub-committee of the Registrar General's Advisory Committee on Medical Nomenclature and Statistics.

The statistical aspects of measuring sickness have recently become more and more important but there is often confusion about the appropriate indices to be used. This Sub-committee was appointed, following a request by W.H.O., to " make preliminary reports on methods of measuring morbidity and on the terms by which morbidity rates and indices should be described ".

The Sub-committee recommends the "spell " of sickness and the sick person as alternative basic units because, in general, these are counted most easily. The report contains definitions of terms used and of the various rates suggested, together with their application to various types of sickness surveys and records.

In the words of the Registrar General's preface, this report has been published " in order to encourage the experimental use of definitions proposed in it, to stimulate wider discussion of the subject and to provoke constructive criticism ". Its subject intimately concerns all industrial medical officers who should consider the use of the measures proposed and who should be among the best suited to produce the " constructive criticism " wanted.

N. M. GOODMAN

Industrial Dust, 2nd ed. By Philip Drinker and Theodore Hatch. (Pp. x + 401 ; 148 figures. 71*s.* 6*d.* ; $10.00.) New York, London and Toronto : McGraw-Hill Book Co. Inc. 1954.

This second edition of a book which on its first appearance was greeted as a standard work is a welcome event. In the past 20 years or so a great amount of work has been done on all aspects of the dust problem in industry. Readers of this journal are well aware of the many extensive medical studies that have been carried out. Side by side with these there have been important investigations of the nature of various dusts, of methods of sampling and examining dusts, including microscopic methods, and of the mechanics of dust particles. New methods for the control of dusts have been devised and old ones improved, and the principles of air filtration have been investigated and applied to respiratory protective devices.

The results of recent work are incorporated in this new edition which contains nearly 90 more pages than its predecessor. In general arrangement the new edition is much the same as the old one, but some parts are much expanded and here and there some paragraphs have been dropped.

The initial chapter on the physical properties of dusts, fumes, and mists contains much new material. The earlier discussion of the effects of dusts and fumes upon man is much extended, and there is in addition a new chapter on dust retention by man. A new chapter on the appraisal of dustiness deals with such considerations as frequency of sampling, weighting of dust exposures, the volume of a sample, and the accuracy required. Sampling instruments are discussed in the light of recent investigations and there is a valuable comparison of such instruments. In the examination of airborne dusts the determination of particle size is of great importance, and this topic is discussed at some length. The remaining chapters on control of the dust hazard, local exhaust systems, air-cleaning apparatus, filtration, and dust respirators and air masks have all been overhauled and largely re-written.

A vast amount of work has gone into the preparation of this new edition with the result that the book is thoroughly up to date. As is well said in the authors' preface, control of the dust hazard in industry is the joint duty of the physician and the engineer. The book is written from the engineer's standpoint, but it will be invaluable also to the industrial doctor who so often has to appraise the value of a dust control system. The book is well worthy of its distinguished authors. It is well produced and well indexed.

THOMAS BEDFORD

Modern Occupational Medicine. Edited by A. J. Fleming, C. A. D'Alonzo, and J. A. Zapp. (Pp. 414 ; 44 illustrations, 1 in colour. 75*s.*) London : Henry Kimpton. 1954.

This book is a collection of papers written by 20 members of the staff of the American firm E. I. du Pont de Nemours and Company. It is an account of the service provided in an important but limited field of industrial medicine by a group of men whose opinions are naturally influenced by the special nature of their work and environment. This explains the choice of some subjects and the important omissions from a book whose title leads one to expect a more informative and comprehensive study than is actually given. Many of the papers are in fact little more than a competent précis of information that can now be found in several modern textbooks, but the editors explain their concise form by the fact that the book is intended to be " useful to physicians, executives, safety engineers, and chemists in industry ".

In his introductory chapter the Medical Director describes the functions of an occupational medical service, which to be adequate must include an exhaustive annual medical examination for every worker and provide a full-time physician for every thousand individuals employed. The need for medical staff on this scale becomes apparent when it is appreciated, for instance, that there are well over 200 items in the form of signs and symptoms or diseases to be recorded for every prospective employee. It is advocated that every initial examination should include a chest radiograph, a blood count, an audiogram, and a Wassermann test or its equivalent ; in addition routine electrocardiograms are recommended on all applicants of 40 years of age or over. The Company employs 130 full-time and 36 part-time physicians.

The latter half of the chapter entitled " History of Industrial Medicine " is devoted to the admittedly notable contributions made by the United States during the twentieth century including an enthusiastic tribute to Dr. Gehrmann, the du Pont Medical Director. English pioneers in the field are sadly neglected in this paper and the work of Sir Thomas Legge, for example, is dismissed in a few words.

In a comparatively long paper Dr. Foulger discusses the factors that produce what he terms " stress ", or slight deviations from the " normal " in otherwise healthy workers, and simple practical means of estimating this state. The principle that Dr. Foulger has so long advocated is commendable but his methods of estimation are still controversial and generally unacceptable.

There follow three chapters that describe the investigation of the toxicity of new chemicals, the protective devices available for workmen, and the important contribution made by an industrial hygiene laboratory in maintaining a healthy factory environment. These are admirably concise accounts of valuable assets to a medical service in a chemical industry.

The chapters on " Physical Environment ", " Fatigue ", " Inplant Feeding " (canteens), and " Chemical Health Hazards " contain items of interest but are too brief to provide much more than a summary of established knowledge. Dr. Fleming, for example, gives an authoritative account of chemical hazards but has only half a page to spare for lead, mercury, or phenol compounds, while a whole chapter is devoted by one of his colleagues to chemicals affecting the carotid sinus. " Industrial Noise " and " Radioactive Hazards " are subjects that must now be included in any book of this kind and

here they appropriately follow the paper on physical environment. There is surprisingly no reference to lighting and colour in factories.

One might have expected the special prominence given to medico-legal aspects to which an entire chapter is devoted and there are repeated references throughout the book to the growing practice of litigation. Initial medical examinations, medical records, and even treatment may have legal implications at a later date, and every accident involves a probable claim for compensation. One cannot help sympathizing with the contributor who describes at length the necessary qualities of a good medical witness and with our professional colleagues in America who are apparently so often involved in these disputes.

Two unusual papers on the problem of anxiety states among employees offer methods of treatment that will seem strangely unorthodox to the English mind. They recommend in general what is described as effective discipline which condemns " a policy of humoring and appeasement . . . or rearranging the external environment to suit his (the patient's) fancied needs ". This seems to imply a firm hand by supervisor and doctor working conjointly, a policy which will apparently produce better results than other forms of therapy and in particular " preoccupation with long histories and diagnostic minutiae ".

The book has some surprising omissions and there is little or no information, for example, on the pneumoconioses, the occupational traumatic, infective and malignant diseases, or the health of young persons and the elderly. Several papers will seem almost rudimentary to industrial medical officers but the majority compensate for their lack of detail with bibliographies which in a few instances are quite impressive. The book is nevertheless a notable achievement by the staff of one firm although it is obviously intended more especially for the benefit of safety engineers and chemists. The general picture of the work of a medical service in a large industrial enterprise of international repute is well depicted and should be studied by everyone concerned with occupational health. The opinions of our American colleagues are stimulating and provide food for thought, however unpalatable in some respects to us in Great Britain.

D. KENWIN HARRIS

The Casualty Department. By T. G. Lowden. (Pp. viii + 278 ; illustrated. 37*s.* 6*d.*) London and Edinburgh : E. & S. Livingstone. 1955.

Although Mr. Lowden has written his book primarily for the guidance of young men and women taking up casualty work, it can also be read with profit by those responsible for the treatment of the injured in industry. The clinical features of the common conditions likely to be met with in a casualty department are well described and the treatment advised is generally in accordance with accepted modern thought, but it is surely questionable whether many people suffering from acute tenosynovitis are still subjected to absolute fixation of the limb and a prohibition on work for three weeks. Nevertheless, the author's recommendations are in most respects very sound and it is greatly to be hoped that heed will be taken of what he has to say about the proper use of penicillin and other antibiotics.

Mr. Lowden obviously knows his working men, for after describing the classical treatment for sprained finger and mallet finger he admits that they do not usually find it acceptable.

He lays stress on simplicity as the keynote to restoration of function and quite rightly considers that " repeated function of the injured member in ways it is used to does more to restore ability than twice as much organized exercise ". But, he does not overlook the importance of good treatment from the outset and is strongly of the opinion that the best way of avoiding compensation neurosis is " to get the patients well of their organic conditions swiftly and effectively : to maintain an atmosphere of optimism and efficiency : to establish a reputation for rapid recovery and good results —to be good at the job. If everyone gets better in a few days no one has time to become neurotic ". In fact the perfect picture of the well run works surgery !

A deep understanding of the many problems which arise in dealing with industrial injuries and of the importance of a right approach to the patient runs right through this book and sets a pattern which would save many thousands of man/hours every year if it were followed by all accident surgeons. Attention is drawn to the importance of maintaining close touch with industrial health departments, and the help that may be obtained by drawing on the experience of their medical officers is emphasized. Special praise is given to the arrangements made by the Association of British Chemical Manufacturers and used by its member firms.

The organization of a casualty department is described fully and the legal aspects are also dealt with in considerable detail.

This book is well produced, well illustrated, and most readable : it should be in the hands of all industrial medical officers.

G. F. KEATINGE

The Halogenated Hydrocarbons ; Toxicity and Potential Dangers. P.H.S. Pub. No. 414. By W. F. von Oettingen. (Pp. ix + 430 ; $2.50 cents.) Washington : U.S. Govt. Printing Office. 1955.

In the field of toxicology Dr. von Oettingen is probably at least as well known for his literary compilations as for his experimental contributions. The present volume is cast in a characteristic mould calculated to arouse the admiration of the reader for the assiduity rather than for the imagination of the author. In just over 400 pages some account is given of about 320 compounds. For a majority little more than bare data on their physical and chemical properties is given. Nevertheless, the fact that no reference is made to work describing the biological properties of a compound may be taken as good evidence that no such publication yet exists. This seems to be a reasonable deduction from a study of the accounts of well known compounds. Here the author has combed the literature both of America and Europe with great care and also included references to works that must have a very limited circulation.

In a brief preface the author expresses the hope that the publication of this book may help to reduce the incidence of poisoning by those compounds which he discusses. To achieve this it would have been much improved if in each case he could have included a few lines of practical advice to the non-medical reader who might turn to the book to find out whether or not he should handle a particular compound with special care. For a book with such an aim the reader may perhaps be surprised to find that the largest section (42 pages) is devoted to D.D.T. which has never been regarded as presenting any serious industrial or user hazard, while a notorious poison like methyl bromide has only 14 pages. The next largest review is that on carbon tetrachloride, but this probably in part reflects the apparent fascination this compound holds for experimental pathologists studying liver damage.

This is essentially a reference book in which brief summaries of published work are strung together with little or no attempt to discuss the significance or importance of the observations in respect of the one to the other. This makes reading difficult. The difficulty is exacerbated by the repeated use of the same openings for paragraph after paragraph. The book lacks any imprint of the author's own views on the subjects he discusses so that it is difficult to believe that it will, as he hopes, "stimulate research on the many problems unanswered". No problems are defined and the reader is left to seek for himself the gaps in existing information, the filling of which would make a significant advance in knowledge. The few attempts made to discuss the comparative toxicity of some of the series of compounds described are little more than summaries of what has already been stated.

There are a great many minor spelling mistakes but none so striking as the rendering of trichloroacetic acid on pp. 209–210. The heading in the middle of page 203 is incorrect. The text in many places could have been condensed to table form where compounds about which little or nothing is known are described.

Despite the criticisms made above there is no doubt that this will remain an invaluable reference book. The author is to be thanked for the thoroughness with which he has compiled this book which is available at the very reasonable cost of $2.50.

J. M. BARNES

Backache in Women. By E. Schleyer-Saunders. (Pp. 80; 6 figures. 7*s*. 6*d*.) Bristol: John Wright. 1955.

Much has been written in the medical press on the subject of backache in women—a complaint which many sufferers have accepted as an inevitable accompaniment of childbearing and the menopause, or, of later years, have been pleased to be labelled as another case of "slipped disc". This little book presents a classification of the causes of backache with their differential diagnosis, and suggests methods of prevention and treatment, though no great advance is claimed in the latter. Gynaecological, orthopaedic, and rheumatic groups are considered, and it is stated that 50% of all cases show some gynaecological pathology. Emphasis is laid on static and postural faults as a causative factor in all groups whatever the underlying pathology and some useful and simple diagnostic procedures are described.

The book is clearly presented and easily readable and will be of particular interest to general practitioners. It will have little appeal to the industrial medical officer though it may serve once again to draw his attention to postural defects and strain, which frequently arise from inadequate seating accommodation at work, incorrect siting of machines and their operators, and inefficient methods of lifting and handling heavy packages.

A. LLOYD POTTER

BOOKS RECEIVED

(Review in a later issue is not precluded by notice here of books recently received.)

The Invasive Adenomas of the Anterior Pituitary (Sherrington Lecture No. III). By Sir Geoffrey Jefferson. (Pp. 63; 24 figures. 5*s*.) The University Press of Liverpool. 1955.

Baillière's Handbook of First Aid and Bandaging, 4th ed. By A. D. Belibios, D. K. Mulvaney, and K. F. Armstrong. (Pp. xii + 464; 200 figures. 8*s*. 6*d*.) London: Baillière, Tindall & Cox. 1955.

Vitamins in Theory and Practice. By L. J. Harris. (Pp. xxii + 366; 103 figures. 35*s*.) London: Cambridge University Press. 1955.

The National Corporation for the Care of Old People. Seventn Annual Report for the Year Ended 30th September, 1954. (Pp. 40). London: Nuffield Lodge. 1955.

Klinische Electropathologie. Part I by S. Koeppen; Part II by F. Panse. (Pp. xii + 424; illustrated.) Stuttgart: Georg Thieme Verlag. 1955.

Report on the Health of the Royal Air Force and Women's Royal Air Force for the Year 1951. London: Air Publications and Forms Store.

Wiederherstellung der Lebenstüchtigkeit geschädigter Menschen. By H. Hoske. (Pp. xii + 217. DM. 16.–.) Stuttgart: Georg Thieme Verlag. 1955.

Central Mining—Rand Mines Group: Health Department. Report for the Year 1954. Johannesburg: Dr. A. J. Orenstein, Rand Mines Ltd. 1955.

Clinical Orthopaedics, Number Five. Edited by Anthony F. DePalma. (Pp. viii + 242; illustrated. Subscribers 40*s*. per copy; single copies 60*s*.) London: Pitman Medical Publishing Co. 1955.

Student Almoner. By Josephine Kamm. (Pp. 192. 7*s*. 6*d*.) London: Bodley Head. 1955.

Textbook of Occupational Therapy. By Eamon N. M. O'Sullivan. (Pp. x + 320. 21*s*.) London: H. K. Lewis. 1955.

Why Have Pain. By Molly Turner. (Pp. iii + 23; illustrated. 2*s*.) Shrewsbury: Wilding & Son. 1955.

Joint FAO/WHO Expert Committee on Nutrition. Fourth Report. (Pp. 58. 3*s*. 6*d*.) London: H.M. Stationery Office. 1955.

Wiederbelebung. By H. Killian and A. Dönhardt. (Pp. viii + 321; 93 figures. DM. 24.–.) Stuttgart: Georg Thieme Verlag. 1955.

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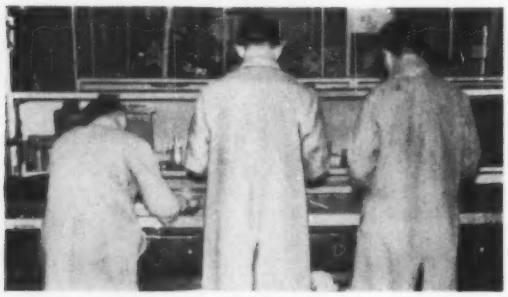

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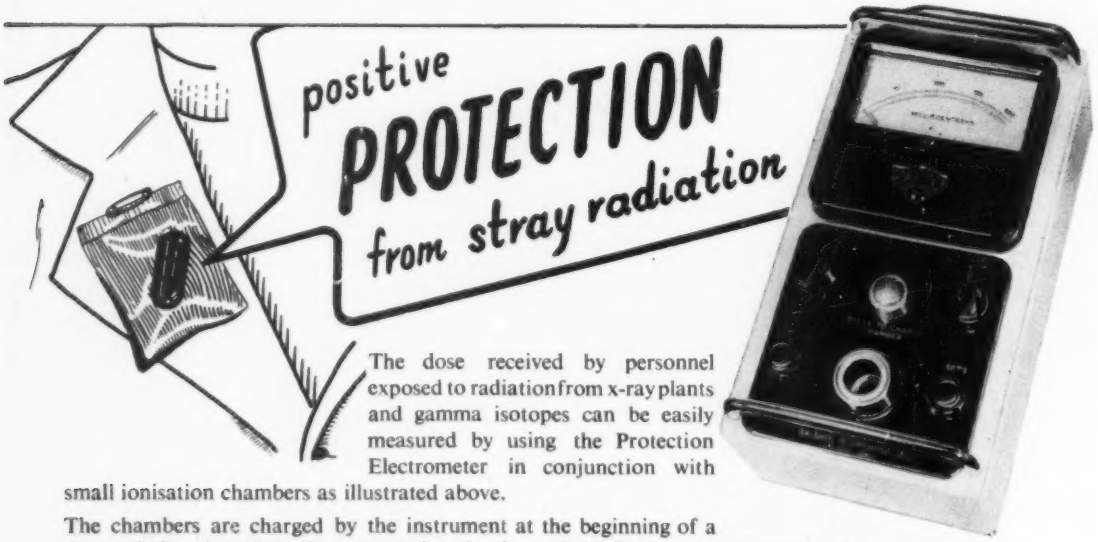

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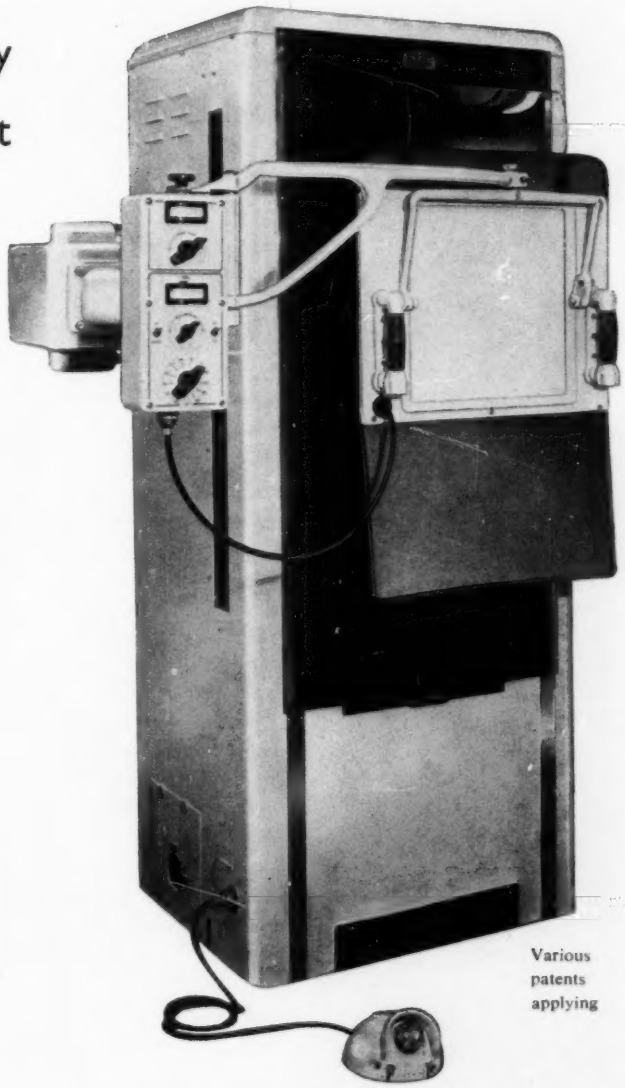

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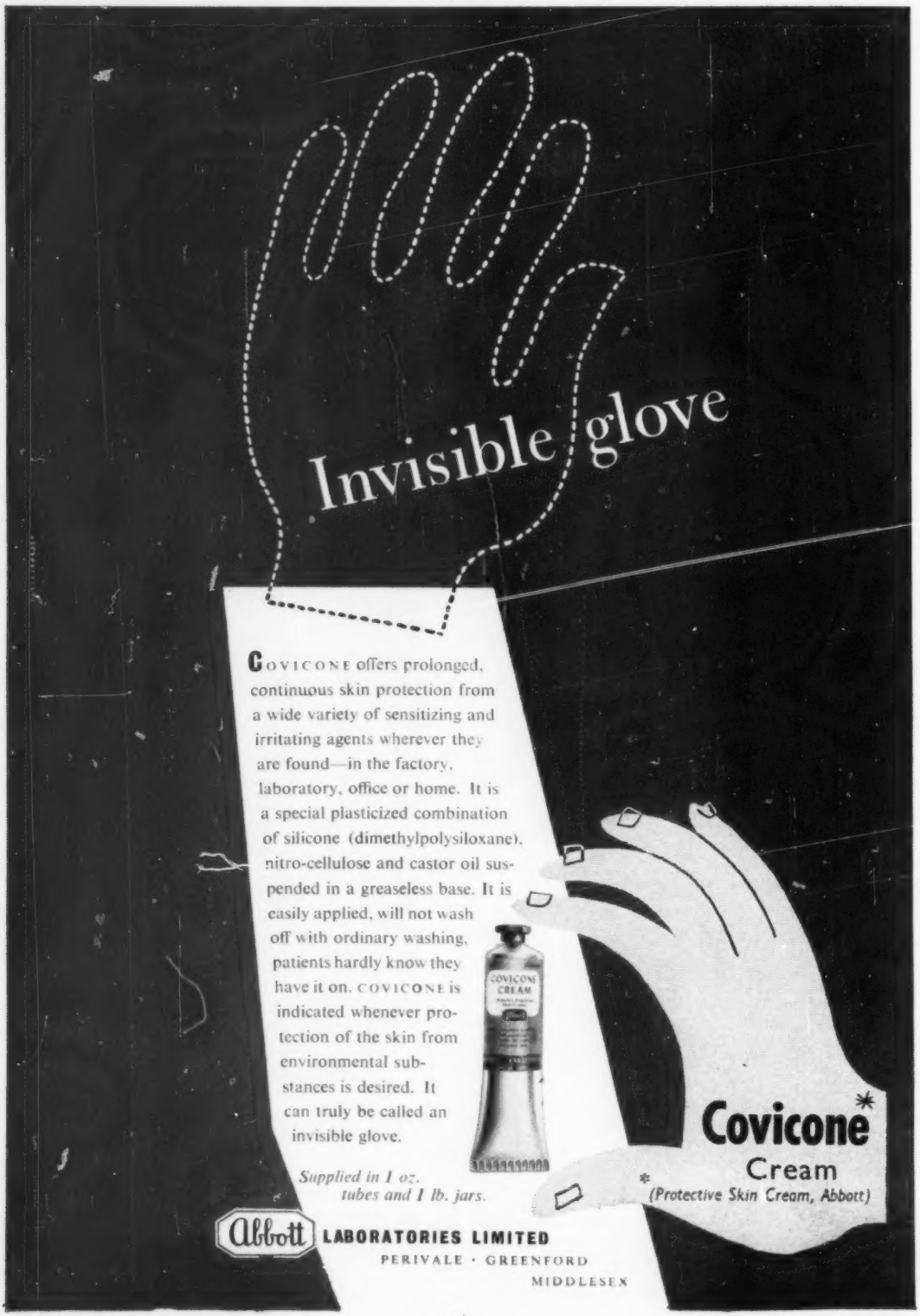
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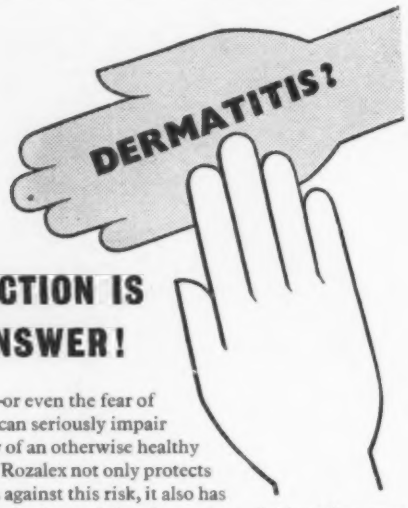

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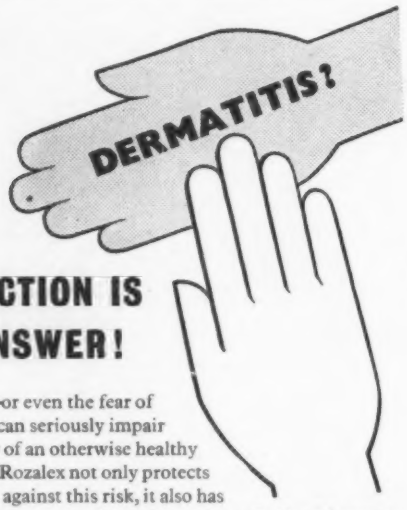

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